MARINE DIESEL OIL ENGINES

VOLUME II.

MARINE DIESEL OIL ENGINES

A MANUAL OF

MARINE OIL ENGINE PRACTICE

FIFTH EDITION—In Two Volumes

VOLUME II.

COMPLETELY REVISED, RE-CLASSIFIED, AND WITH NEW EXHAUSTIVE
INDEX. THE WORK IS ALSO NOW THOROUGHLY UP-TO-DATE

*CONTAINS EXHAUSTIVE NOTES AND SKETCHES DESCRIP-
TIVE OF THE PRINCIPLE, CONSTRUCTION, AND RUNNING
OF LARGE MARINE SETS; ALSO FAULTS, WITH THEIR
CAUSE AND REMEDY, ETC. ARRANGED AS A TEXT-BOOK
FOR THE BOARD OF TRADE EXAMINATIONS, FOR OIL
MOTOR CERTIFICATES, ENDORSEMENTS, AND "PERMITS."
CONTAINS ANSWERS TO ALL BOARD OF TRADE NEW
"ENGINEERING KNOWLEDGE" QUESTIONS FOR OIL MOTOR
EXAMINATIONS*

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SECTION IX

QUESTIONS AND ANSWERS ON MARINE DIESEL OIL ENGINE PRACTICE

Similar to those given at the Board of Trade Examinations
under the title of "Engineering Knowledge Questions"

4-CYCLE AND 2-CYCLE ENGINES

No.	QUESTION.	ANSWER.
1	Describe clearly the cycle of a 4-stroke Diesel engine.	See p. 1.
2	Sketch an exhaust valve. What is it made of? How is it actuated? What is its action?	See pp. 77 (No. 32), 78, 82 (No. 36), 269.
3	Sketch out a set of valve levers and show how operated.	See pp. 78 (No. 36), 132, 183.
4	How is the timing of the valves altered?	See p. 28.
5	What is meant by the term "lay shaft"?	See pp. 4 (camshaft), 5.
6	Sketch the actuating gear of a cylinder fuel injection valve.	See p. 78 (No. 34).
7	If the exhaust valve refuses to close, what may happen?	If the exhaust valve refuses to close owing to, say, a broken spindle, the piston on coming up may strike the valve and send it home on to its seat, or, which is more likely, the valve spindle may be bent or the valve face broken. If the valve is sticking partly open, some of the exhaust gases will be drawn into the cylinder on the suction stroke, and on the compression stroke the air will be forced through the exhaust valve in place of being compressed; also when the charge of fuel is injected into the cylinder, it may escape through the exhaust valve opening into the exhaust pipe, and set up combustion at that position. This fault may therefore be considered a serious one.

No.	Question.	Answer.
8	Sketch a fuel pump and explain how it is timed.	See pp. 13, 19, 27, 270, 393, 556, 782, 833, 836.
9	Sketch out a method of reversing for 4-stroke engines.	See pp. 54, 60, 131.
10	Give the maximum compression pressures and temperatures found in 4-cycle and 2-cycle Diesel engine cylinders, also the terminal pressures and temperatures for each. Explain clearly the difference between the two, if any, and state the cause of same.	See pp. 29, 30.
11	Describe or sketch out a diagram, showing the timing of the starting air cycle of a 4-stroke Diesel engine.	See pp. 288, 336.
12	Describe a 4-stroke engine diagram, showing where each operation begins and ends ; also draw a low spring diagram for the inlet and exhaust stroke.	See pp. 299 (No. 230), 301, 320.
13	Give definitions of "indicated thermal efficiency," "mechanical efficiency," and "scavenge efficiency," and how these apply to 4-stroke and 2-stroke engines.	See pp. 19, 20, 22, 32, 52, 292, 736 (No. 541).
14	Sketch out a timing diagram for a 4-stroke engine cycle.	See p. 286.
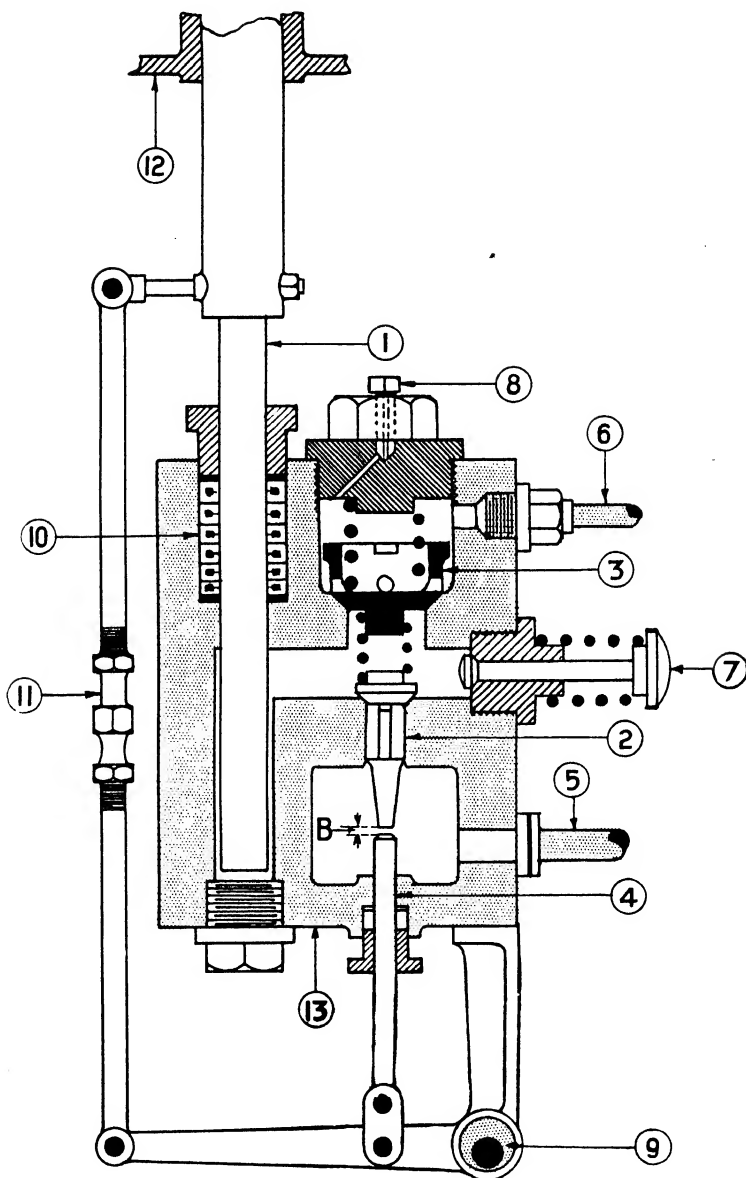
No. 440.—Fuel Pump.

(Referring to Question No. 8, page 555.)

1. Pump plunger.
2. Suction valve.
3. Delivery valve.
4. Tappit rod.
5. Fuel inlet to pump.
6. Fuel delivery to cylinder fuel valve.
7. Hand priming pump.
8. Air lock pins (when eased back air locks are broken).
9. Eccentric for tappit lift regulation by hand or governor control.
10. Metallic packing with grease core.
11. Tappit regulation rod.
12. Guide for pump plunger.
13. Pump body fitted with relief valve.

The pump plunger is usually driven by an eccentric on the camshaft (not shown). The clearance B is equal to ·004″ ($\frac{1}{10}$ millimetre) when the plunger is placed at the "full out stroke" position with the handle in "running" position and governor arms open. In the case of solid injection engines the governor is arranged to control simultaneously both the fuel pump suction valve lift and the lift of the cylinder fuel valve. This provision is necessary to maintain the same pressure in the fuel pipe when running at reduced loads as at full loads. A relief valve is also fitted on the delivery side of the fuel pump in the case of solid injection engines. Glandless pumps are now usually fitted, the plungers being "lapped" or ground to form a "push" fit in the pump chamber. The fuel pumps of solid injection engines are usually provided with double crossheads to ensure that the plunger will always find its correct alignment position.

NOTE.—By "full out" is meant the position of pump eccentric drive, or limit of plunger "in" stroke.

No.	QUESTION.	ANSWER.
15	Sketch a fuel injection valve. Explain how the amount of oil is regulated for various speeds.	See pp. 15, 16, 17, 18, 19, 27, 71, 77, 268.
16	What is the approximate temperature of the exhaust gases?	About 550° F. for 2-stroke engines, and 750° F. for 4-stroke engines.
17	Why does the exhaust valve of a 4-stroke engine usually show signs of wear first?	Owing to the scouring action of the high temperature gases which pass through.
18	Give the average lift of the fuel valve and of the exhaust valve.	About $\frac{3}{16}$ in. or $4\frac{1}{2}$ mm. for the fuel valve. About 2 in. or 50 mm. for the exhaust valve. (For engines of about 2000 B.H.P.)
19	Mention difficulties sometimes experienced in starting up 4-cycle engines, and how these are overcome.	If the atmospheric temperature is low, trouble may be experienced in starting up the engines on fuel. This may be overcome by admitting steam of low pressure into the cylinder jackets to assist the heat of compression; also by heating the fuel in the settling tanks to lower the viscosity of the oil, which, it should be noted, varies inversely as the temperature. To facilitate starting up from cold in some cases a steam connection is led to the cylinder jackets to raise the temperature of the liners. Before starting it is necessary to prime up the fuel pumps by hand to ensure that the fuel pipe up to the valve is completely filled and that no air locks exist, otherwise the engine might refuse to pick up on fuel after cutting out the starting air. If trouble is experienced in starting on fuel the timing of the fuel valve might require to be slightly altered.

No.	QUESTION.	ANSWER.
20 ,	Describe the construction of the cylinder head of a 4-cycle Diesel engine. How is the head secured to the cylinder? What troubles are cylinder heads subject to?	The cylinder head is of cast iron, and is formed with suitable recesses for the fitting of the various valves and for water-jacketing purposes. The head is bolted down to the cylinder casting by means of ten or twelve long heavy bolts, and is fitted with five valves, as follows :— 1. Fuel inlet valve. 2. Air suction valve. 3. Exhaust valve. 4. Air starting valve. 5. Relief valve (750 lbs.). Cylinder heads are subjected to severe heat stresses which sometimes result in the formation of cracks. The cracks, in most cases, extend between the fuel valve and exhaust valve, or between the fuel valve and air suction valve seats. Deposits of lime are also apt to form in the jacket space of the head, when sea-water cooling is employed, if the outlet temperature is high.
21	Referring to Harland & Wolff engines, what may cause the starting air-slide to stick?	If the engines have been running ahead for a long period, the lubricating oil may have been lost, and the valve would stick when manœuvring operations are begun. The oil supply to the valve should, however, be limited in quantity, as otherwise danger of explosion may exist, owing to the generation of explosive gases. A few drops of oil supplied to the valve chest at long intervals only, should be sufficient.
22	Referring to a normal 4-cycle Diesel engine diagram, state in atmospheres the average compression pressure, firing pressure, exhaust pressure, and M.I.P. which should be obtained under good conditions.	Compression pressure = 32·5 atms. or kg. Firing ,, = 37 ,, ,, ,, Exhaust ,, = 2·5 ,, ,, ,, M.I.P. ,, = 6·4 ,, ,, ,, And, 32·5 atms. × 14·22 = 462 lbs. ,, 37 ,, × 14·22 = 526 ,, ,, ,, 2·5 ,, × 14·22 = 35·5 ,, ,, ,, 6·4 ,, × 14·22 = 91 ,, ,,

No.	Question.	Answer.
23	Describe the piston water cooling tubes of Harland & Wolff engine.	On the piston is fastened the outer tube and inside of this the inner tube, which fits into the recess in the piston, and is secured in place by a lantern nut, the latter screwing into a thread on the bottom of the outer tube and keeping the inner tube jointed hard into the piston recess.
		A locking ring is screwed on top of the lantern nut in order to lock it and prevent it from working back. On the inside an internal tube is fitted, which has a small woodite ring piston on one end and on the other is screwed a small flange with a rubber ring for a joint. This tube is stationary and takes its pumping action from the up and down stroke of the piston. The joint is made on a casting bolted to the side of the frame from which the circulating water enters. On the outside of this pipe arrangement is fitted a large iron tube, which on top is fixed to the distance piece by a flange, having on top a neck ring, fitted with two woodite rings for the smooth working of the outer tube. On the bottom it is fixed to the same bracket as the internal pipe, but only the outlet water passes through this one. See pp. 78 (34) 94 (55 and 56).
24	High speed engines are often of the 4-cycle type: why is this so?	The thermal efficiency of 2-cycle engines being usually slightly lower than that of 4-cycle engines, it follows that with increase of revolution speed the thermal efficiency will fall off more rapidly in the case of 2-cycle engines than with 4-cycle engines. Reduced time per cycle results in reduced scavenge efficiency. It should also be mentioned, however, that with increase of revolution speed the volumetric efficiency of 4-cycle engines is also reduced.

No.	QUESTION.	ANSWER.
25	Are high speed engines more efficient than low speed engines; and if so, why?	Within certain limits high speed engines are more efficient than low speed engines, for the reason that the temperature is kept more uniform and combustion is thus more complete. If an engine speed is reduced to, say, 10 revs. per min., firing would not take place owing to the dissipation of the heat of compression. If, again, the engine speed is excessive, difficulty might be experienced in getting rid of the heat generated, and the engine might overheat to a serious extent. For these reasons a high speed 4-cycle engine is more efficient than a high speed 2-cycle engine.
26	Describe clearly the cycle of a 2-stroke Diesel engine.	See p. 1.
27	At what point of the stroke is maximum pressure attained?	Maximum pressure is reached at " firing " position where the pressure may rise from, say, 500 lbs. at compression to 560 lbs. at firing. See p. 289.
28	For about what fraction of the stroke does the fuel valve remain open?	For about $\frac{1}{10}$ to $\frac{1}{8}$ of the stroke travel.
29	In the 2-stroke type, what is the usual scavenge air pressure?	About $1\frac{1}{2}$ lbs. without supercharge, and from 3 to 5 lbs. with supercharge air.
30	Sketch out a timing diagram for a 2-stroke engine.	See p. 297.
31	Compare the merits and demerits of 2-stroke and 4-stroke engines.	See pp. 10, 11.

No.	QUESTION.	ANSWER.
32	Referring to the 2-stroke Diesel engine, how is exhaust carried out if no exhaust valves are fitted?	By means of exhaust ports cast in the cylinder liner near the bottom end, and through which the exhaust gases pass out when the ports are uncovered by the piston on its downstroke. See p. 186.
33	Show by a sketch how the fuel valve lift can, in some cases, be controlled to suit variation of engine load.	See pp. 183, 803.
34	Sketch out a method of reversing for 2-stroke engines.	See pp. 183, 185, facing p. 214.
35	Describe the action of the fuel pump of a solid injection engine other than the Doxford type; also describe briefly the action of the cylinder fuel valve.	See pp. 202, 905-909.
36	State the effects of low volumetric or scavenge efficiency on combustion.	If the volumetric efficiency is low, combustion is affected adversely, as the air supply drawn in is reduced in weight quantity.
	What is super-charging, and how does it affect the thermal efficiency and power developed by the engine?	By "supercharging" (Sulzer system) is meant that a secondary supply of supercharge scavenge air is delivered to the cylinder through a special row of upper ports, after the exhaust ports have closed. See p. 190 (No. 132). Supercharging improves the thermal efficiency and increases the power output by as much as 15 per cent. See pp. 108 (No. 66, a, b, c), 783, 789.
37	Enumerate the fittings and valves required in 2-cycle engines.	Two-cycle engines require a fuel valve, an air starting valve, and a relief valve in the cylinder head. The liner is arranged with scavenge air ports on one side and exhaust ports on the other side. The working valves are loaded by spring compression and are opened by means of levers, cams, and cam rollers. See pp. 183, 184, 188.

No.	QUESTION.	ANSWER.
38	Describe the action of the Sulzer 2-cycle engine air starting valves.	The small pilot compression release valve is closed during normal conditions of running, but when the gear is in "start" position this valve lifts after compression release has taken place. In doing so, it admits a small quantity of the starting air to the scavenge receiver, as the air pressure is now balanced on either side of the pilot valve. The main starting air valve also lifts and admits air to the cylinder through the cylinder starting valve, which remains open during the actions just described. When the gear is placed in "start" position the cylinder air valve opens first, followed in rotation by the opening of the pilot valve and the opening of the main air valve, as described. See also p. 189.
39	Why are turbo-blowers or electric-driven blowers now used extensively for scavenge air in 2-cycle engines?	Because they can deliver a larger volume of air at a low pressure. They also ensure a steady supply at a constant pressure. Should steam auxiliaries be fitted, exhaust steam can be used for the turbine. If electric auxiliaries are fitted, then motor drive is used. See pp. 783-789.
40	State the advantages and disadvantages of valve scavenging and port scavenging.	See p. 717.
41	Referring to 2-cycle engines, describe what may happen if the piston skirt is not a close fit in the cylinder walls.	If the crosshead guides have excessive play, or the piston skirt is an easy fit in the cylinder, there will be danger of the hot exhaust gases of combustion blowing back into the crank case when the piston has travelled upwards past the exhaust port openings.
42	Describe how choked pulveriser rings may affect the action of a fuel valve.	If the fuel valve atomiser rings become choked, carbon deposits are likely to form round the fuel valve seating and result in the valve becoming leaky.

No.	QUESTION.	ANSWER.
43 *	Mention the special advantages claimed for the N.B. double-acting sliding cylinder type engine.	Reduced heat stresses as the heat transfer is divided between the separate sections of the cylinder construction. Reduced friction owing to the cylinder moving with the piston during part of its travel. Elimination of gland packing. Increased power output for a given engine-room space. Absence of wire drawing in scavenge and exhaust.
44 *	Describe a type of oil engine with two pistons in each cylinder.	The Doxford engine and the Cammell-Laird engine have two pistons (opposed) in each cylinder. See pp. 9, 203, 240.
45 *	Describe or sketch out the opposed piston type of Diesel engine.	1. **Doxford.**—In this type of opposed piston engine the cylinder liner consists of a long, thin, open tube of special cast iron, arranged with suitable ports for scavenge air at the lower end, and exhaust at the upper end, small openings being also cast for the air starting valve and the fuel valve at the centre. The lower piston rod connects to the centre crank, and the upper piston rod to a crosshead above, which actuates a pair of side links coupled to the two outer cranks. Firing takes place at the "in" position of the pistons, solid fuel injection being employed, the oil pressure ranging from 4000 to 5000 lbs. per sq. in. A scavenge pump, driven by a crank or lever, supplies the necessary air at a pressure of about $1\frac{1}{2}$ lbs. per sq. in. Also see p. 203. 2. **Cammell - Laird - Fullagar Opposed Piston Engine.**—In this type of opposed piston engine, two cylinders and two cranks form one unit, the diagonal rods of the upper piston of one cylinder being connected

No.	QUESTION.	ANSWER.
45	—*Continued.*	to the crossheads of the lower piston of the opposite cylinder. The general construction of the liners is similar to that of the Doxford engine. Blast air fuel injection is employed, and the scavenge air is obtained by means of low air pressure pumps formed by extensions of the rods of the upper pistons. Also see pp. 9, 240.
×46	Mention the advantages claimed for opposed piston type oil engines.	See pp. 10, 12.
×47	Describe a type of double-acting Diesel engine.	In this type of oil engine the 2-cycle system is usually adopted, the engine firing on both the downstroke and upstroke, or twice per revolution. Fuel valves are fitted at either end of the cylinder, together with air starting valves, exhaust ports and scavenge ports being also required, top and bottom. In the North British type of double-acting Diesel engine, designed by Mr J. Maclagan, each cylinder is divided and connected by means of struts, the piston trunk working in the open space between with crosshead pins which connect with the double link type connecting rod. The cylinders are arranged to slide or travel vertically for about 13 in., the piston stroke being about 42 in. This cylinder movement obviates the necessity for glands, permits easy exhaust and scavenge port timing, and reduces heat stresses. The cylinder heads are held securely in position by means of heavy crossbeams, and the movement of the two halves of the cylinder is obtained by the action of levers fulcrumed on one column, the other ends being driven by the crosshead pins.

No.	Question.	Answer.
47	*—Continued.*	The cylinder heads are packed against gas leakage by Ramsbottom rings fitted similarly to piston rings.
		The reversing gear only requires the exertion of hand power, and the fuel valves are arranged with single cams, which, on being rotated through an angle of 30° by hand, are suitable for either ahead or astern running as required.
		The N.B. type of engine works most efficiently at high jacket cooling water temperatures, the practice recommended being to allow an inlet temperature of about 120° F. and an outlet temperature of 150° F.
		The special advantage of the double-acting engine lies in the large power obtained in a small fore and aft engine-room space, each cylinder being able to develop about 1000 I.H.P., or 4000 I.H.P. in the case of a 4-cylinder engine set. The compression pressure is about 490 lbs. per sq. in. and the firing pressure 550 lbs. per sq. in., the blast air pressure 1000 lbs. per sq. in. and the scavenge air pressure 1·5 lbs. per sq. in.
		Double-acting engines are also constructed by Messrs Harland & Wolff, Werkspoor, Worthington, Richardson's, Westgarth, and other firms.
		Also see pp. 89, 102, 110, 151.
48	How is the reciprocating motion conveyed from the two pistons to the crankshaft?	Referring to question No. 45, each single unit consists of a pair of cylinders, the crossheads of which are cross-connected by means of diagonal rods.
		The connecting rod of each lower piston is coupled direct to the crankpin of the same cylinder.
		Also see pp. 206, 240.

No.	QUESTION.	ANSWER.
49	Describe briefly the Scott-Still engine.	In this combination type of engine the 2-cycle Diesel principle is applied on the upper surface of the pistons and steam on the under surface, the steam being generated in water tube boilers (after starting) by means of the heat of the waste gases of combustion from the Diesel end of the cylinders. Starting and manœuvring is carried out by steam obtained from the auxiliary boiler. The solid injection system of fuel injection is employed, thus doing away with the necessity for air compressors. The steam cylinders work on the compound principle with one H.P. cylinder and the others low pressure, and the exhaust steam from the cylinders is afterwards utilised to drive a turbine blower which supplies low pressure scavenge air to the oil end of the pistons. A small condenser, air pump, etc., is also fitted. See pp. 252-262.
50	Describe the principle of the "Cammell-Laird-Fullagar" opposed piston type Diesel engine.	Two pistons work in opposite directions within the cylinder, which is therefore equal in length to two strokes. Firing takes place at the centre of the cylinder and between the pistons when both are at the "in" position. See pp. 9, 239.
51	Describe the principle of the Junker's opposed piston type Diesel Engine.	See diagram to face p. 10 (No. 5).
52	Explain what is meant by the "solid injection" system.	See pp. 17, 18, 22.
53	Mention the merits of the solid injection system of fuel supply to cylinders.	See pp. 17, 18, 22, 23.

No.	QUESTION.	ANSWER.
54	Sketch out a type of solid injection fuel valve.	See diagram to face pp. 202, 208.
55	Describe a 4-cylinder engine constructed on the "Junker" principle, also give the crank sequence.	The Doxford opposed piston type 2-cycle engine is a modification of the original "Junker's" engine, with the upper cylinder omitted (see p. 203). For a 4-cylinder engine the firing sequence would be—1, 4, 2, 3. In the Doxford engine the crankshaft lengths are bolted to the crank webs by means of a flange (p. 746), so that if the crankpin or webs become damaged, removement and replacement can be easily and quickly carried out.

GENERAL OIL ENGINE PRACTICE
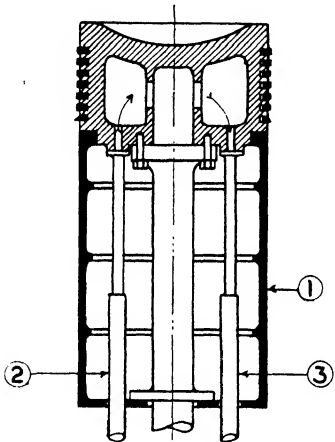
No.	QUESTION.	ANSWER.
56	If a piston cracked, how would it show?	If a piston cracked the cooling system would fail to operate, and steam, together with gases of combustion, would be seen to issue from the piston cooling pipe outlet.
57	What should be done in the above case?	If it is not possible to stop the engine and remove the defective piston, cut out the cylinder by opening the fuel by-pass and shutting off the blast air supply. Also shut off the piston cooling water. To avoid loss of power due to compression, remove the air suction valve and free the exhaust valve. See p. 870.
58	If the engines have been standing idle for some time, what precautions are taken before starting to ensure that the cylinders do not contain water?	Take a full turn of the engine with the turning gear and leave indicator cocks open. Whenever engines are stopped it is also advisable to keep open all compressor drains to prevent accumulation of water through leaks, etc.
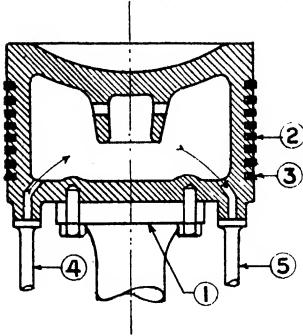
No.	QUESTION.	ANSWER.
59	What may cause water to accumulate in cylinders?	If cracks develop in the cylinder head, these tend to open when cold and close up under running conditions by the effects of heat expansion. Water may accumulate in this way when engines are stopped.
60	If the cracks do not take up when running, what would be the effect?	The water circulation of the head would be affected, as, on the firing stroke, the gases would blow into the water circulation spaces. During the suction stroke water would be drawn into the cylinder, with the result that combustion would be adversely affected, with probable misfiring, also danger of smashed cylinder head.
61	Referring to the previous question, what should be done if the engine cannot be stopped?	Cut out fuel and blast air of that cylinder, also shut off the water circulation and remove the air suction valve and disengage the exhaust valve so that the compression may be relieved and power saved.
62	What is the cause of burning at the end of the fuel valve spindle?	The valve spindle may become burnt through the blast air pressure being low, the pulveriser rings choking up, or the valve leaky.
63	What is meant by priming up of fuel valves before starting?	By means of the hand priming pumps fitted on the front of the fuel pump chest, the fuel pipe is charged up with fuel oil before starting, the handle being placed in running position to ensure that the suction valves will seat themselves. The by-pass valves also require to be opened to ascertain if the fuel is flooding up to the cylinder valve, two or three strokes of the hand priming pump being usually found to be sufficient.
64	If the exhaust valve of one cylinder in a set is leaky, how can this be detected without taking off diagrams?	By opening the test cocks on the exhaust pipes, from which smoke and flame will be seen to issue if the exhaust valve is leaky. When ignition takes place, detonations will also be heard in the exhaust passage.

No.	QUESTION.	ANSWER.
65	What may cause exhaust valves to stick?	Exhaust valves may gum up through excessive lubrication. Asphalt deposits from the fuel oil will also produce sticking of the valves.
66	What is the effect of a leaky air starting valve when the engines are running?	Exhaust gases would pass back into the air starting system, causing overheating and possible sticking of the master air slide valve. (Also danger of explosion.) The cylinder starting valve pistons (H. & W. type) would be raised, causing the push-rods and cams to come into contact. The engines should be stopped and the leaky valve removed and replaced without delay.
67	Give the causes of leaky exhaust valves.	1. The hot exhaust gases flowing at high velocity exert a cutting action on the valve and seat. 2. Carbon or other solid matter in the fuel held between the valve and seat and forced into the metal by the hammering action of the valve. 3. Corrosive effect of acid present in the fuel. 4. Valve or spindle warping by the heat and upsetting the truth of the valve when in seated position.
68	What is the clearance usually allowed between the butts of piston rings?	An amount equal to about $\frac{2}{1000}$ of the cylinder diameter, or more. For a cylinder of, say, $25''$ diameter, the clearance between the butts would be about $\cdot050''$, as $\frac{50''}{1000} = \cdot050''$. <div align=center>NOTE.—$25'' \times \cdot002'' = \cdot050$.</div>
69	How are cylinder water jackets and heads cleaned of sand sediment or lime deposits?	By using a half-and-half solution of spirits of salt and fresh water. Allow the solution to remain for twelve hours, and after draining off, clean out with water. Also by the use of "Clensel."
70	If the exhaust valve closes early, how may this be noticed and how remedied?	By hearing a whipping noise in the air-suction inlet pipe. By slightly reducing the diameter of the round portion of the valve cam disc and readjusting the valve roller clearance.
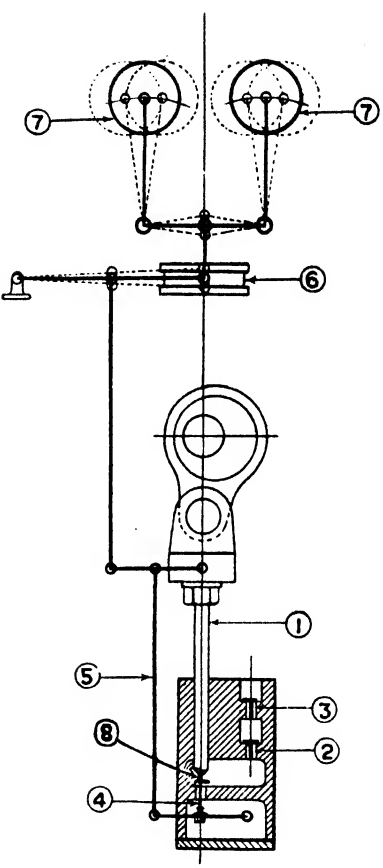
No.	QUESTION.	ANSWER.
71	If the air suction valve is leaking, how will this show when running?	By sparks appearing at the air inlet pipe slots.
72	How can the tightness of a fuel valve be tested?	Put reversing gear in mid-position and open up the blast air bottle connection to the cylinder ; if the valve is leaky, the pressure will fall in the blast air bottle, and air will be heard to escape through the indicator cock if opened.
73	How are fuel valves reground and cleaned?	The valve seat is ground with carborundum powder, followed with slate powder. The atomiser is cleaned with paraffin.
74	Give a complete list of causes of smoky exhausts.	1. Overload. 2. Choked air inlet slots. 3. Unsuitable fuel. 4. Choked exhaust. 5. Excessive resistance in pulveriser rings. 6. Blast air pressure low. 7. ,, ,, high. 8. Leaky fuel valve. 9. Low compression. 10. Late ignition. 11. Fuel valve lift incorrect.
75	State the position at which the fuel valve opens and for what fraction of the stroke it remains open. What adjustments should be made with regard to the fuel when the engine load is reduced?	The fuel valve opens about 5 before the top centre, and remains open for about 45°, which is equal approximately to $\frac{1}{10}$ stroke. When the load is reduced the fuel supply should also be reduced, and the blast air pressure lowered to, say, 600 lbs. or thereabout. The governor acts to reduce the fuel supply when the load falls off ; but this can also be carried out by means of hand control. In some cases the cylinder fuel valve lift can also be reduced by means of hand control gear.

No.	QUESTION.	ANSWER.
76	Explain why piston rods are made of large diameter in the body and of much smaller diameter at the position of the cross-head nut.	To withstand the heavy initial body load on the piston and resultant compressive stress, the piston rod requires to be of heavy construction. As, however, the compressive load is finally transmitted to the crosshead, it is sufficient for the rod to be much less in diameter at the position of the screw. The tensile stress on piston rods may be considered as negligible.
77	Sketch out a piston for a Diesel engine, and show the method of piston cooling usually adopted.	

No. 441.—Piston of 2-Cycle Diesel Engine.

1, Piston "skirt."
2, Piston cooling water inlet.
3,   ,,   ,,   ,,   outlet (140°).

The oil scraper ring is fitted to retain the lubricating oil on the liner walls and piston rings.

Observe that the piston rod is secured to the piston by means of a flange and eight or ten studs.

The 2-cycle engine piston requires a deep skirt which is separate, and secured to the piston body by a flange and pins.

The piston extension, or "skirt," is fitted to ensure that on the "top" position of the piston the scavenge or exhaust ports will not be uncovered under the piston.

No.	QUESTION.	ANSWER.
77	Continued—	

No. 442.—Piston of 4-Cycle Diesel Engine.

1, Piston rod flange.
2, Piston packing rings.
3, Oil scraper ring.
4, Piston cooling water inlet.
5,   „   „   „   outlet ($140°$).

No.	QUESTION.	ANSWER.
78	Explain the meaning of clearance volume, also describe how it can be measured with fair accuracy.	By clearance volume is meant the cubic volume contained between the piston and cylinder head when the crank is on the top centre.

The suction air is compressed in the clearance space.

The clearance volume can be calculated approximately by employing "Simpson's Rule" as shown below.

Cylinder, 26 in. diameter; stroke, 35 in.; piston head dished as shown, and lineal clearance (as tested), 2 in.

Then,

$$\frac{(3\cdot5'' \times 4) + 2'' + 2''}{6} = 3'' \text{ mean lineal clearance.}$$

Clearance volume $= 26^2 \times \frac{11}{14} \times 3'' =$
                                            1593 cub. in.

Then,

Clearance volume to stroke volume $=$

$$\frac{1593 \times 100}{26^2 \times \frac{11}{14} \times 35''} = \begin{cases} 8\cdot5 \text{ (approximate) per cent.} \\ \text{of stroke volume.} \end{cases}$$

No.	QUESTION.	ANSWER.
79	Why is high compression economical in Diesel engines? How is pre-ignition guarded against in the case of hot-bulb semi-Diesel engines with a fair degree of compression? State effects, and show by a diagram.	Compression being approximately adiabatic, the heat produced by the work done on the air gas is recovered, with only slight loss. Another advantage is that ignition of the fuel oil charge is obtained by means of the high air-compression temperature (1100° F.). In hot-bulb engines pre-ignition is avoided either by correct regulation of the bulb temperature by water circulation or by the actual injection of a small quantity of fresh water directly into the cylinder and by the timing of the fuel admission (also see p. 460, etc.).
80	If steam is used for heating up the cylinders before starting, what is the pressure and for how long a period is the heating carried out?	The steam pressure used for the heating up of cylinder jackets is from 50 to 75 lbs. gauge. The steam is kept on the jackets for a period of about three hours.
81	The bearing surface of a thrust block of the rocking pad type in sustaining a load of 200 to 300 lbs. per sq. in. has a coefficient of friction of ·0015. Explain clearly the effect which the adoption of such a thrust would have on the propelling machinery.	The coefficient of friction for a thrust block of the standard horse-shoe type is, under the best conditions of running and design, never less than ·01 or 1 per cent., whereas with a thrust block of the Michell oil film type the coefficient is only about ·0015 or ·15 per cent. From this it will be evident that the power saved by reduced friction losses when a Michell block is fitted will be equal to $$1 - ·15 = ·85 \text{ per cent.}$$ In other words, 1 per cent. of the power is absorbed by friction in one case and only ·15 per cent. in the other, or, about $\frac{1}{7}$, as $1 \div ·15 = 7$ nearly. The frictional losses are therefore reduced by $\frac{6}{7}$, which will result in increased propulsive efficiency and economy. If, say, 7 I.H.P. is used up in friction with a horse-shoe thrust block, and a Michell thrust is substituted, only 1 I.H.P. will then be absorbed.

No.	QUESTION.	ANSWER.
82	Sketch out and describe a governor for an internal combustion engine driving an electrical generator.	

No. 443.

1, Pump plunger.
2, 3, Delivery valves.
4, Tappet which controls lift of suction valve.
5, Regulating link connected to governor gear.
6, Sliding collar.
7, Governor weights.
8, Suction valve.

Sec p. 86 (No. 49).

No.	Question.	Answer.
82	—*Continued.*	The governor is fitted to the end of the vertical shaft which drives the cam-shaft. It has two weights which work two pawls attached to a loose sleeve in the vertical shaft, the sleeve being kept in position by a spring which can be adjusted to give the speed required by altering the compression by means of a screw fitted on the top. When link (5) is lifted by the action of the sliding collar (6), the tappet (4) is raised and holds the suction valve off its seat during a portion of the down-stroke of the pump. See p. 86 (No. 49).
83	Describe how the cutting out of one cylinder is effected without stopping the main engines.	To cut out one cylinder of a set, shut off the fuel, and adjust the tappet-pin screw of the fuel pump so that the suction valve will be raised clear of its seat. If the exhaust or air suction valve (4-cycle engine) cannot be conveniently jammed open, to relieve the compression, only partly close the blast air connection, as otherwise the fuel valve will become unduly heated.
84	Describe how the exhaust gases are utilised in Scott-Still and in other internal combustion engines.	Exhaust gases are often utilised to generate steam of about 100 lbs. pressure in auxiliary boilers of the Clarkson or Cochran type. Oil fuel burners are also fitted to supplement the heat of the exhaust gases which are of themselves sometimes insufficient, or for port use. The gases leave the cylinders at a pressure of about 35 lbs. gauge and a temperature of 750° to 900° F., and represents about 30 per cent. of the total heat of combustion generated by the fuel. The evaporation obtained from the waste gases on a basis of " from and at 212° " is about 1 lb. of steam per B.H.P. hour. See pp. 812-815.

No.	QUESTION.	ANSWER.
85	Describe how piston rings are manufactured. Also state the usual allowance given for butt clearance.	1. A cylindrical casting or "pot" is made of special cast iron and sufficient in depth to permit of the production of a number of piston rings, and this is bored out inside and turned roughly to the required dimensions with allowance for joint. 2. The rings are next parted off to the thickness required, after which a milling machine is employed to cut out the spaces for the joint, the corners being then rounded off by hand tooling work. 3. The rings are now strung on to a parallel mandril, with the joints closed, and, having been clamped firmly in this position, are turned on the outside to the finished size plus allowance for grinding. 4. The rings are next taken off the mandril and put into a female type jig for boring out concentrically on the inside to size required. 5. The rings are next "peened" by hand on the inside, sufficiently to require a force of about 60 lbs. to close up a $\frac{7}{16}$ in. opening at the joint. 6. The rings are finally ground by an emery machine to exact finished sizes at top and bottom edges, also on the outer and inner surfaces, the latter being also given a smooth finish. 7. The rings are now tested by being placed in a cylinder bore jig, and tried at all points with $\frac{1\cdot5}{1000}$ in. feelers which should not pass through anywhere. The clearance at the ends of the rings ranges from $\frac{1}{1000}$ to $\frac{1\cdot5}{1000}$ in. per inch diameter, so that a 27-in. diameter ring would be given a butt clearance of, say, $\frac{40}{1000}$ in.

No.	Question.	Answer.
86	Sketch out a character-istic Diesel engine cylinder indicator diagram, and describe or show how to calculate the M.I.P.	See pp. 284, 299 (Nos. 230, 231).
87	What is the meaning of B.H.P. or S.H.P., and what proportion of the I.H.P. does it average?	By B.H.P. is meant the actual or effective H.P. which is being transmitted along the line of shafting to the propeller; or, in other words, the I.H.P. with the H.P. used up in friction, air compressors, scavenge pumps, etc., deducted. B.H.P. of 2-stroke engines = about 76 per cent. of I.H.P. B.H.P. of 4-stroke engines = about 78 per cent. of I.H.P. Also see pp. 20, 21.
88	Sketch out an indicator diagram and show by dotted lines the effects of "leaky piston rings."	See p. 291 (No. 220).
89	Sketch out an indicator diagram and show by dotted lines "leaky air inlet valve."	See p. 291 (No. 220).
90	Sketch out an indicator diagram and show by dotted lines "choked or dirty silencer."	See p. 291 (No. 221).
91	Sketch an indicator diagram and show by dotted lines "slots in air inlet pipe choked up."	See p. 290 (No. 218).
92	Give the rule to calculate the I.H.P. of one cylinder of a 4-stroke Diesel engine.	$$\frac{\text{Cyl. area in } \square'' \times \text{stroke in ft.} \times \text{revs.} \times \textbf{M.I.P.}}{33000 \times 2} = \textbf{I.H.P.}$$

No.	QUESTION.	ANSWER.
93	What is the spring scale usually employed for Diesel engine indicator diagrams ?	The scale used is often 1 mm., is equal to 1 kg. per sq. cm. ; or 14·22 lbs. per sq. in. This is equivalent to about 360 lbs. per in. height, as the following calculations will show :— $$1 \text{ kg.} = 2\cdot204 \text{ lbs.}$$ $$1 \text{ sq. cm.} = \cdot155 \text{ of } 1 \text{ sq. in.}$$ Then, $\dfrac{2\cdot204 \times 25\cdot4}{\cdot155} = 360$ lbs. per in. $$25\cdot4 \text{ cm.} = 1 \text{ in.}$$ Or, $2\cdot204 \div \cdot155 = 14\cdot22$ lbs. per sq. in. per mm.
94	Describe how indicator cards are taken off and how M.I.P. is calculated, also I.H.P. Explain how a cylinder constant is obtained.	Indicator diagrams are taken by means of an indicator which is fixed to the cylinder, and the paper drum of which is actuated by a cord connected to some reciprocating part of the engine. To find the M.I.P. divide the diagram up into two half-end divisions and nine whole divisions between, then apply the scale of the spring employed, say, $\frac{1}{400}$, and measure the length of each ordinate. Take the sum of these and divide by ten to obtain the M.I.P. Then, I.H.P. (4-cycle engine)= $$\frac{\text{Piston area}\boxed{''} \times \text{stroke in ft.} \times \text{revs.} \times \text{M.I.P.}}{33000 \times 2}$$ Cyl. Constant=$\dfrac{\text{Piston area}\boxed{''} \times \text{stroke in ft.}}{33000 \times 2}$ Then, I.H.P.=Constant × Revs. × M.I.P.
95	If the I.H.P. by calculation is 600 and the B.H.P. by tests 480, find the mechanical efficiency of the engine.	Then, Mech. Eff. $= \dfrac{480}{600} = \cdot80$, or 80 per cent.
96	Compare the thermal efficiency of Diesel engines with triple expansion engines and steam turbines.	Triple expansion engine = 14 per cent. thermal efficiency on I.H.P. basis. Turbine engine = 18 per cent. thermal efficiency on S.H.P. basis. Diesel engine = 34 per cent. thermal efficiency on B.H.P. basis.
97	Give definition of " Mechanical Efficiency."	Mechanical Efficiency $= \dfrac{\text{B.H.P.}}{\text{I.H.P.}}$. Also see pp. 29, 21.

No.	QUESTION.	ANSWER.
98	Give definition of "Heat Efficiency," or "Thermal Efficiency."	Thermal Efficiency $= \dfrac{\text{Work got out in ft.-lbs.}}{\text{Work put in in ft.-lbs.}}$ EXAMPLE.—Fuel consumption = ·4 lb. per B.H.P. per hour. Calorific value of fuel = 18500 B.T.U. Find brake thermal efficiency. Then, Work got out = 33000 × 60 = 1980000. ,, Work put in = ·4 × 18500 × 778 = 5757200. So that, Brake Thermal Efficiency $= \dfrac{1980000}{5753200} = \cdot342$ or 34·2 per cent. Also see pp. 598, 736.
99	What is a "kilogram-metre" equal to in foot-lbs.?	Then, $\dfrac{2\cdot2 \times 39\cdot37}{12} = 7\cdot2$ ft.-lbs. 2·2 lbs. = 1 kg. 39·37″ ,, = 1 metre.
100	What conditions are necessary for the efficient combustion of oil in a Diesel engine cylinder?	1. Good compression. 2. Clean fuel and free from water. 3. Correct timing of cylinder fuel valve. 4. Correct blast air pressure. 5. All cylinder valves tight. 6. Correct setting of fuel pump.
101	When the oil is blown into the cylinder, how is combustion effected?	The minute particles of oil become intimately associated with the oxygen of the heated atmospheric air, chemical combination, known as combustion, takes place, and heat is generated.
102	How is ignition obtained in the following cases—(a) petrol engines; (b) semi-Diesel engines; (c) full Diesel engines?	(a) By electric spark. (b) By low compression and hot bulb or hot surface plate. (c) By high temperature of air compression.
103	What adjustments should be made when the engines have worked up to normal conditions?	The adjustments to be made on the main engines when they have worked up to normal conditions are: Equalising the power in each cylinder by adjustment of fuel pumps. Power developed to be found from indicator cards. The temperature of the discharge water should also be equalised for all cylinders, and the exhaust gas temperatures should all be similar.

No.	QUESTION.	ANSWER.
104	What should be the appearance of the exhaust gases when the engine is working satisfactorily?	Funnel gases should be of light grey colour, but under best conditions the gases are quite colourless.
105	Previous to stopping the engines, what precautions should be taken?	Previous to stopping the engines, care should be taken that the blow-off valves on the air bottles and regulating heads are closed, otherwise the air pressure will fall off; also starting air tanks to be fully charged.
106	Mention what defects may cause the engine to refuse to start.	Loss of compression through leaky exhaust valve, inlet valve, or fuel valve cover joint. Starting valve sticking up; air lock in fuel pump or pipe line; turning gear not taken out.
107	What effects are produced by worn or broken piston rings?	Broken piston rings allow the gases to leak past the piston, thus reducing the compression and power of the engine. The cylinder liner may also be damaged by bad scoring, and may also heat up.
108	What causes may produce pre-ignition?	Pre-ignition may be caused by — Oil lying on piston top and admitted by leaky fuel valve, which ignites before piston reaches top centre. If fuel valve timing is too early, the same will happen. High temperature of blast air. Low blast air pressure. Leaky fuel valve.
109	Describe how to test if each cylinder is developing approximately equal power.	(a) By taking off diagrams, working out same for each cylinder, and then comparing the results obtained. (b) If cards are not available, cut out the fuel supply of each cylinder of, say, eight, in turn, and note revolutions obtained with only seven cylinders working: if, say, with No. 5 cylinder shut off the revolutions suddenly increase, then No. 5 will be developing less power than the others, and should be tested for the fault. (c) By pyrometer readings of exhaust gas temperatures.

No.	QUESTION.	ANSWER.
110	How much more than the noted power should each cylinder be allowed to develop?	Not more than, say, 10 or 15 per cent., as the initial load on the crankpin might set up serious stresses on the shafting.
111	What may be the cause of incorrect firing?	Faulty timing of fuel valve. Excessive blast pressure or low blast pressure. Fuel valve sticking. Water in fuel oil. Leaky valves in cylinder head.
112	Describe the construction of a fuel valve.	The fuel valve case is constructed of high grade cast iron and the pulveriser of mild steel, with five or six rings and distance pieces between each. Slots are cut on the outer edges of the rings. A non-return valve is fitted to keep the air from being blown back into the fuel pump. A by-pass valve is also fitted to ascertain if the fuel is rising to the cylinder, also that no air lock is present.
113	Sketch out, or, if preferred, explain fully how the starting air is cut out and the fuel put in.	See pp. 69, 174, 180.
114	How is the lift of the fuel valves altered?	See p. 183.
115	After grinding a valve, how should the valve be finally cleaned before replacing?	All grinding powder should be carefully removed and the valves cleaned with some soft cloth fabric; a touch of light oil is also advisable.
116	If the bottom end bushes or main bearing bushes wear down, what effect would this have on the compression stroke of the cycle and on the power of the engine?	The piston clearance volume would be increased and the compression reduced, which would affect the efficiency and power of the engine. Combustion would be imperfect, and starting up difficult.

No.	QUESTION.	ANSWER.
117	Describe how a cylinder liner is put into the cylinder. What allowance is made for expansion? Also explain how water joints are made.	The liner is fitted from the top downwards, and fits in position by means of one or more fitting strips. The liner is held down in position by the cylinder head, which checks into a groove turned on the upper flange face of the liner. Liners are usually turned to a taper, being thinner at the lower end. Expansion is allowed for in a downward direction. Water joints are made of rubber rings, and gas joints of copper rings.
118	What is the usual temperature of compression obtained in a Diesel engine cylinder?	From about 1000° to 1150° F.
119	What may cause poor compression in the cylinders?	See pp. 22, 383.
120	Describe the effects of a thick carbon deposit on the piston head of (1) a marine Diesel engine; (2) an air cooled petrol engine.	Heavy carbon deposits on the piston head would reduce the clearance volume. If the deposit remained at a red heat pre-ignition might take place.
121	What may cause knocking in the engines?	See pp. 384, 392.
122	What conditions must exist in the cylinder of an internal combustion engine to give good combustion?	For first part of question, see p. 580 (Question No. 100).
	How is this improved or otherwise?	By the timing of the fuel valve, etc.
	What are the products of complete combustion and of incomplete combustion?	CO_2 and water vapour (H_2O) from complete combustion, and CO and black smoke from incomplete combustion.
	What is the percentage of air to fuel (a) for maximum power; (b) for maximum efficiency.	About 22 lbs. of air to 1 lb. of fuel for maximum power, and about 35 lbs. of air to 1 lb. of fuel for maximum efficiency. In the case of maximum power, the consumption per B.H.P. hour will therefore be more than with maximum efficiency.

No.	Question.	Answer.
123	Why is high compression economical?	Because it allows of efficient combustion taking place.,
	(a) How is comparatively high compression obtained in 2-stroke explosive engines without pre-ignition?	(a) By scavenge air at a pressure of about 3 lbs. per n, obtained by crank case compression, and which is compressed to about 200 lbs. n.
	(b) What effect has this on the construction?	(b) Requires an airtight crank case and air inlet valves.
	(c) How does it affect the indicator diagrams?	(c) Diagrams show a higher back pressure.
124	Describe how a marine Diesel engine is fixed to the hull of a merchant ship. Illustrate your answer with sketches, showing bedplate, special seating (if any), double bottoms, etc.	See diagram to face pp. 274, 275, 277.
125	Mention the minimum and maximum temperature of cooling water at outlet of cylinders and pistons you would work to.	Cylinders - - 100° min.; 140° max. Pistons - - 120° ,, 160° ,,
126	Give a list of the preparations you would consider necessary before starting up the main engines.	Before starting up main engines :— (1) Starting air compressors to be started up and starting air reservoirs charged to working pressure of 350 lbs. per sq. in. (2) Blast air bottles to be charged up to 1000 lbs. per sq. in. (3) Lubricating oil pumps to be started up and oil pressure raised to 10 lbs. per sq. in. (4) Circulating and piston cooling pumps to be started to test if in working order, and to circulate water just before engines are started. (5) Main engines to be turned 2 revs. by turning gear to ensure all clear, then turning gear to be withdrawn. (6) Fuel oil pumps on main engine to be flooded with oil, and fuel pipes to fuel valves on cylinder head charged up with oil by the hand gear. (7) Reversing gear to be tried over several times.

No.	QUESTION.	ANSWER.
127	What may cause the engines to slow down?	See p. 382.
128	What may cause the engines to run fast?	See p. 383
129	What may cause the engines to smoke?	See p. 385.
130	What may cause the engines to run irregularly?	See p. 384.
131	How often, if possible, should the exhaust valve be removed for examination?	Exhaust valves should be removed for examination every six weeks or two months.
132	How often should the fuel valve be taken out for examination?	Fuel valves may be examined every six weeks or two months.
133	How is the working of the engine affected by—	
	(a) Water in the fuel oil.	(a) Engine would slow down, or fuel valves may stick.
	(b) Oil too thick.	(b) Might cause fuel valve to hang up, or might close up pulveriser ring openings.
	(c) Leaky fuel valve.	(c) Knocking in cylinder due to misfiring and generation of dangerously high pressures. Engine may slow down as blast is too high for fuel.
	(d) Fuel pump wrongly set.	(d) Engine might not start on fuel. ,, ,, misfire. ,, ,, smoke.
	(e) Fuel valve sticking in open position.	(e) Certain cylinders might not fire. Blast pressure would fall. Fuel valve spindle would become burnt. Danger of pre-ignition and resultant high pressures in cylinder.
	(f) Leaky piston rings.	(f) Reduced compression and reduced engine power; also rapid wear of rings, which may finally seize in their grooves owing to want of lubrication.

No.	QUESTION.	ANSWER.
133	*—Continued.* (*g*) Choked lubri-cating system.	(*g*) Cylinder liner would fire up and might crack. Bearings would become heated up and develop knocks. White metal might run out of bearing bushes.
	(*h*) Blast pressure too low.	(*h*) Engine would smoke, and might develop knocking in cylinders.
	(*i*) Unequal fuel oil distribu-tion to each cylinder.	(*i*) Engine would smoke, and power developed in each cylinder would be unequal, throwing heavy stresses on the crankshafting. Diagrams should be taken off each cylinder, and after working out, the powers developed should be com-pared.
	(*j*) Air in fuel pump.	(*j*) The engine might stop through an air lock in fuel connections.
	(*k*) Fuel valve lift insufficient.	(*k*) Engine would smoke and power would fall off.
134	Where are escape or relief valves usually fitted?	Escape valves are fitted on the cylinder heads, also on the air bottles, air tanks, inter-coolers, and fuel pumps.
135	Sketch out a fuel pump and show how con-trolled.	See p. 19.
136	Sketch out a fuel valve cam and show method of adjustment.	See pp. 267, 601 (No. 194), 746 (No. 566).
137	If the fuel valve sticks open, what may happen?	If the fuel valve sticks open there will be a serious loss of blast air, and if engine is being started the high pressure air may prevent engine from turning the top centre. If the engine is running and the fuel valve hangs up, too much blast air will be admitted to the cylinder, which may lead to pre-ignition and heavy knock-ing. The indicator diagram would show a high maximum pressure. Back firing through the fuel valve may also occur, with danger of bursting the fuel pipe and blast air pipe.

No.	QUESTION.	ANSWER.
138	Show by sketches the difference between air inlet valves, fuel valves, exhaust valves, and starting valves.	See diagram, pp. 71, 76, 77, 81, 82, 96, 154, 269, 271.
139	Sketch out a Diesel piston, showing cooling arrangement.	See pp. 24, 74, 75, 94; facing pp. 154, 200.
140	Describe fully how to reverse a Diesel engine.	See pp. 30, 61, 84, 178, 185.
141	What are a Chief Engineer's duties when a ship is dry docked for survey?	As in the case of steam-driven vessels, the ship's skin fittings should be all gone over; also the stern tube, tail shaft, and propeller fittings should be carefully examined.
142	What may cause an engine to be sluggish in starting; also what might cause a kick back?	(a) A leaky air starting valve might allow a quantity of air into other cylinders from the one on which the start is being made. (b) A leaky fuel valve would produce similar results, as high pressure air will be admitted before the piston reaches the top. Water in cylinder may cause the engine to kick back, but is more dangerous owing to the fact that water is incompressible. A quantity of fuel oil lying on piston top may bring about pre-ignition, with a resultant kick back.
143	What may cause an engine to start away on air but refuse to pick up on fuel?	(a) Fuel pumps air locked, caused by blast air leaking back through the small non-return valves fitted on the fuel valves. (b) By grit sticking on suction and delivery valves of fuel pumps. (c) Oil not being turned on. (d) Fuel pipes not fully charged up with oil previous to start. (e) Loss of compression through leaky inlet or exhaust valves. (f) Piston rings leaking. (g) Compression space increased by loss of liners or by wear down of bearings (top, bottom, or main bearings).

No.	Question.	Answer.
144	On first starting, how is the fuel valve charged up?	The fuel valve is charged up with a small hand plunger priming pump attached to main fuel pump. A small by-pass valve is opened on each cylinder fuel valve, and the hand priming pump operated until the oil is seen to come through; the by-pass valves are then closed, and a few more strokes of the hand pump given to ensure a sufficient supply for starting.
145	Sketch out a cylinder cover and describe how manufactured.	See p. 37 ; facing p. 70.
	What care should be taken during manufacture, and when under running conditions?	In casting every care must be taken in cooling down so as to avoid heat stresses due to excessive or sudden differences in temperature.
	Mention defects that covers are liable to.	See pp. 11, 35, 36.
146	Mention the causes of cracks in cylinder heads and liners.	(a) Heat stresses due to temperature difference on each side of metal thickness. (b) Intense heat of exhaust gases, which often cause cracks between exhaust valve and fuel valve seat. (c) Deposits of scale in water jackets. (d) If atmospheric temperature is low, starting up engines from cold without previous warming up of the jackets with steam. (e) Scale deposit in jackets from sea water circulation and excessive discharge temperature. The lime scale is a bad conductor of heat, and prevents the water from being in actual contact with the skin of the liner metal. Cracks tend to form round openings of any size cut in cylinder liners or heads.

No.	Question.	Answer.
147	Mention the conditions required for efficient combustion in the cylinders.	(a) Cylinder fuel valves to be tight and in correct timing. (b) Piston rings a good fit. (c) Water jacket temperature about, say, 124° F. (d) Piston cooling water temperature about 140° F. (e) Fuel free from water or impurities. (f) Correct blast air pressure. (g) Correct timing of fuel pump.
148	Describe a silencer.	See pp. 472, 872.
149	Describe an auxiliary Diesel engine governor and action of same.	The centrifugal type of governor is fitted to the end of the vertical shaft which drives the camshaft. It has two weights which work two pawls attached to a loose sleeve in the vertical shaft, the sleeve being kept in position by a spring which can be adjusted to give the speed required by altering the compression by means of a screw fitted on the top. (See plate facing p. 86, also p. 280). Fixed to the loose sleeve are forked levers which, by suitable links, connect with the fuel pump eccentric rod tappet shaft. When the engine tends to run fast, the weights spread apart and lift the loose sleeve up on the vertical spindle, thereby working the levers, rods, and eccentric of the fuel pump tappet rod, which is thus raised and holds up the suction valve off its seat for a longer period than before, and thus allows some of the oil to flow back through the suction valve in place of passing through the delivery valve to the cylinder fuel valve. If the engine tends to slow down the reverse action takes place, and more fuel is delivered to the cylinder fuel valve.
150	State the possible effects of unequal power development in each cylinder of, say, an 8-cylinder engine.	If the respective cylinders are not developing about equal power, severe stresses may be thrown on the crankshafting, as the turning moment will be uneven. In a bad case the shaft may be stressed beyond the elastic limit of the material.

No.	QUESTION.	ANSWER.
151	Describe how to find out the cause of unequal power development in each cylinder.	The cause may be :— (a) Faulty fuel pump timing. (b) Choked pulveriser of fuel valve. (c) Leaky cylinder valves on piston rings. Fuel pump should be examined and the cylinder head valves ground in if found leaky. The cam roller clearance may be wrong, or the fuel valve by-pass valve leaky. A card should be taken off to test the compression ; also note exhaust gas temperatures.
152	Describe the construction of a crankshaft for a Diesel engine, and compare the stresses to which it is subjected with those of a steam engine crankshaft.	Diesel engine crankshafting is in some cases of solid construction, and in other cases of built-up construction. Often the crankpins and webs are forged in one piece, the shaft lengths being shrunk on. Engines having four or eight cylinders have the adjacent cranks at 180°, but each pair of cranks are placed at 90° to the next pair. In the case of six cylinders the cranks are placed at angles of 60° to each other. The crankshafting of Diesel engines is heavier than that of steam engines of equal power, as the initial piston loads are in the ratio of about $2\frac{1}{2}$ to 1.
153	Sketch a plan of a Diesel engine-room, showing the various auxiliaries, etc.	See diagram to face p. 358.
154	If the engine-room temperature drops below say, 40°, what precautions should be taken?	If the engine-room temperature drops to below 40°, care must be taken with all water pipes and cylinder jacket spaces, which must be thoroughly drained of all water when not in use, as, if the temperature falls to 32° and under, freezing will take place and the expansion of the water in forming ice would burst the pipes or jackets. Difficulty would also be found in starting up the engine under low temperature conditions, and it may be found advisable to admit heating steam to the cylinder jackets and fuel oil tank steam coils.

No.	Question.	Answer.
155	What is the approximate mechanical efficiency of a triple expansion steam engine, 2-cycle Diesel, and a 4-cycle Diesel, and reasons for the difference, if any?	Triple expansion engine, about 85 per cent. 2-cycle Diesel engine, about 75 per cent. 4-cycle ,, ,, 78 ,, See pp. 20, 21.
156	Give a general description of a Diesel engine cylinder and cylinder head.	These are of special cast iron and are formed with water circulation pockets, recesses for the various valves, and holes to receive the holding down bolts or studs of the cylinder head. The cylinders are usually bolted down to the columns or bedplate, and for piston lubrication purposes four or six small radial openings are bored in the cylinder near the lower end to permit of the fitting of the lubricating oil inlet pipes. The cylinder liner is held firmly in position by means of the cylinder head which is bolted to the cylinder casting, fourteen or sixteen studs being employed for the purpose.
157	Explain how the cylinder valves of a Diesel engine are actuated.	These valves are actuated by means of springs, valve levers, push rods, cam rollers, and cams. The valves are held closed by means of the externally placed springs, and the cam and roller movement transmitted through the push rod lifts up the end of the valve lever and opens the valve against the spring compression either into or out of the cylinder, as the case may be. The camshaft drive is obtained either by spiral wheel gear or by an epicyclic train of wheels from the crankshaft.
158	If the fuel pump fails to deliver the oil supply to the cylinder valves, what might be wrong?	An air lock in the pump would cause the pump to fail in its action. The plugs fitted above the pump delivery valve should be opened to relieve the air lock.
159	What maximum temperature should be allowed for piston cooling discharge water?	Not above 180° for fresh water and 140° for sea water.

No.	Question.	Answer
160	Describe the construction of a cylinder fuel valve.	The fuel valve case is made of high grade cast iron. The pulveriser is made of steel and has a conical piece screwed on the end, with five or six rings and distance pieces between each ring. Slits are cut on the outer edges. A non-return valve is fitted to keep fuel from being blown back into the fuel pump. A by-pass valve is also fitted to ascertain if fuel is getting into valve; also to see if it is free of air lock.
161	If the revolutions are doubled, will the I.H.P. also be doubled?	To obtain double the number of revolutions would require much more than double the I.H.P. for the reason that with constant propeller slip the revolutions are equivalent to ship speed ratio, and, as the B.H.P. is a measure of the consumption, the power would vary nearly to the third power of the revolutions. This would work out as eight times the power required to double the revolutions.
162	With the same adjustment of starting handle, what difference will oil of low viscosity and of high viscosity have on the Indicated Mean Pressure?	For a given notch position of starting handle, a thin oil will give a higher M.E.P. than a heavier oil. It therefore follows that the position of the handle requires to be changed for oils of different viscosity if the M.I.P. is to be kept constant.
163	What is the average speed of the exhaust gases past the valve face?	About 100 to 150 ft. per sec. This velocity combined with the high temperature of the exhaust gases, causes erosion of the exhaust valve faces.
164	Why are Diesel engine pistons usually concave in shape? What is the object?	This shape gives strength and also allows of a good depth of compressed air into which the fuel is injected, this in turn allows the fuel to mix with a large percentage of oxygen, and so efficient combustion is obtained. The atomised oil spray is also more effective on admission to the cylinder in the form of a conical spray.

No.	QUESTION.	ANSWER.
165	State the reasons for explosions taking place in (1) blast air piping; (2) starting air piping; and (3) compressors.	(1) If the cylinder fuel valve is leaky, hot gas may pass back into the blast air piping and be the cause of explosion due to rapid chemical action. (2) If the air starting valve is leaky, hot gas may pass back into the piping and also be the cause of explosion as described. (3) If compressor lubrication is carried to excess, oil vapour may chemically combine with atmospheric oxygen and lead to explosion. The safeguards against explosion are: (1) non-return valves on the air pipe ends; (2) relief or safety discs, which blow when the pressure exceeds the limit set by the disc thickness; (3) by using only the minimum quantity of lubricating oil required by the compressors.
166	Referring to Diesel engine practice, mention the adjustments which should be made when the engine speed and power is reduced.	Under conditions of reduced power and revolutions the blast injection air pressure should be reduced to obtain best efficiency results, and if the gear permits, the cylinder fuel valve opening should be reduced to save loss of blast air. The cylinder cooling water supply may also require to be slightly reduced to promote steady firing. It should, however, be carefully noted that the blast air pressure should never be allowed to fall below, say, 550 lbs., as otherwise there is a danger of back firing occurring above the fuel valve should the blast air pressure fall below that of the cylinder compression pressure. See p. 803.
167	What may cause the engine to " hunt " ?	(1) Blast air pressure high. (2) Air suction or exhaust valve not closing properly. (3) Broken spring in inlet or exhaust valve. Fuel valve lift excessive, or faulty fuel pump valves.

No.	QUESTION.	ANSWER.
168	If a compression diagram is taken off with (1) the engine hot and the fuel cut out, what pressure should be obtained; also (2) with the engine cold?	(1) With engine hot and fuel cut out, a 4-cycle engine should show a compression pressure of about 32·3 atms.; and (2) when cold, about 30·3 atms. $32·3 \times 14·22 = 460$ lbs. per $\boxed{n}$ $30·3 \times 14·22 = 430$　,,　　,,
169	Describe and sketch out a liner for a Diesel engine cylinder. Show how it is secured in position, and how packed.	See pp. 72, 128, 186, 224.
170	What is meant by after-burning?	By this is meant that the complete and final combustion of the fuel is not taking place during the period of fuel valve opening and closing, but is being continued during a portion of the expansion period of the stroke. After-burning represents a thermal loss, as the exhaust gases leave at a very high temperature and less heat energy is therefore converted into work energy. After-burning shows on an indicator diagram by reduced height and increased width. After-burning also reduces the volumetric efficiency.
171	State the effect of unequal power development in each cylinder of a set.	If the total power developed is unequally divided owing to, say, one or two cylinders indicating less than the others the effect will be to give an uneven turning moment on the shaft and in this way increase the stress beyond the safe limit allowed. The engine may also develop a knock. **Causes.** 　1. Faulty fuel pump setting. 　2. Choked fuel valve pulveriser. 　3. Leaky cylinder valves. The fuel pump should be examined and the cylinder head valves ground in if found leaky. The cam roller clearance may be at fault. The fuel valve bye-pass leaking would also cause loss of power.

No.	QUESTION.	ANSWER.
172	Explain why the pressure per sq. in. allowed on crosshead pins is much higher than that allowed on crankpins or main bearings.	The pressure allowed on crosshead pins is about 1100 lbs. per sq. in., and on crankpins about 500 lbs. per sq. in. This difference in pressure per sq. in. is accounted for by the higher surface velocity of the crankpin on its bearing surface, as compared with the low surface velocity of the crosshead pin. The crankpin travels through a circular path, whereas the crosshead pin only swings through the arc of a circle during each revolution, so that the surface velocity of the crosshead is much lower than that of the crankpin or the shaft in the main bearings.
173	Compare the pressure on crosshead guides in the case of steam engine and Diesel engine practice. In certain types of Diesel engine no crosshead guides are fitted; where does the pressure bear in this case?	With a right-hand propeller, the pressure is on the port guide for both the up and down strokes in the case of steam, but with a 4-cycle Diesel engine the guide pressure alternates between the port and starboard guides. On the firing stroke (down) the pressure is on the port guide, but on the compression stroke (up) the pressure is on the starboard guide. If a trunk piston is fitted and no guides, the pressure will then be on the piston and will cause wear on the port and starboard sides of the cylinder liner.
174	Describe the construction of a Diesel engine piston. How is the piston attached to the rod? How is cooling provided for?	Diesel engine pistons are of special cast iron (known as "semi-steel"), and are dished in the upper surface and ribbed inside for strength. The piston rod is flanged at the upper end and is attached to the piston by means of ten or twelve studs. The piston is fitted with from six to eight cast-iron Ramsbottom packing rings, and has, in addition, a lower ring with a knife edge, known as an oil-scraper ring. Telescope piping is fitted to the piston to provide for cooling, and a pressure of about 10 lbs. is supplied by the piston cooling pump, fresh water being employed in some cases only, and occasionally oil.
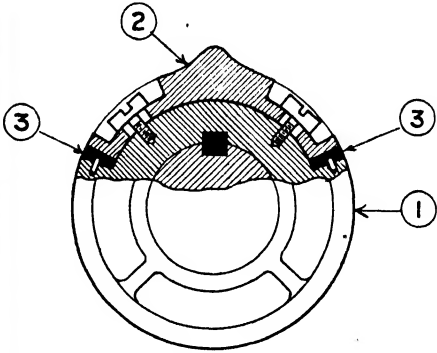
No.	QUESTION.	ANSWER.
175	Referring to Diesel engines, describe how wear down of the crossheads, bottom ends, or main bearings is tested; also describe the effects produced by wear down.	The wear down of crosshead bearings, bottom ends, and main bearings can be tested as follows :— (a) By removing an exhaust valve and inserting a small cylindrical-shaped distance piece gauge, on the top of which is placed some red lead putty. As the gauge is placed in position some of the putty is wiped off, and what is left, plus the depth of the gauge, is equal to the lineal clearance. This reading is then compared with the engineer's record of the original clearance as supplied by the builders. (b) By witness marks screwed on the guides on framing, which give the top centre position of the piston. (c) By measuring between the crank webs with a micrometer telescopic gauge, or a " clock " gauge, at a fixed point, and the engine centred top and bottom (pp. 542, 543). (d) The wear down of main bearings is often taken by means of the usual bridge gauge. The effect of wear down of crosshead, bottom end, or main bearings would be to increase the piston clearance volume and reduce the compression ratio. This would have an adverse effect on the firing stroke, and would also make the engine more difficult to start.
176	Describe how crank-shafting is lined up.	1. Disconnect bottom ends and hang up connecting rods, also camshaft drive gear and compressor drive gear, etc. 2. Take out keeps and top half bearings. 3. Jack up the shaft until coupling faces all fair, or test with bridge gauge for level. 4. Take out bottom half bearings, refill with W.M. and bore out true. 5. Replace bearings, lower shaft into place, and test again before finally connecting up the engine. **Note.—If the wear down is slight and the engine not of large power, liners may be fitted in below the bottom half bearings instead of rebushing the same.**
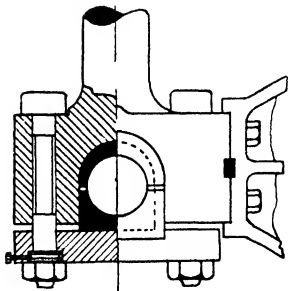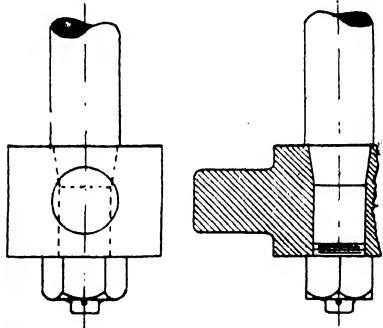
No.	Question.	Answer.
177	If the B.H.P. of an engine is 4000, state the consumption of fuel per 24 hours to be expected in the case of (*a*) Diesel engines ; (*b*) turbines with oil or coal firing; and (*c*) reciprocating engines with oil firing.	Comparison of fuel consumption in a vessel with engines of 4000 B.H.P. (**a**) **Diesel Engines.**—The usual fuel consumption is about ·41 lb. per B.H.P. hour. Then, Fuel per 24 hours$=\dfrac{4000\times\cdot41\times24}{2240}=$ 17·5 tons. (**b**) **Turbines with Oil-fired Boilers.**—The usual consumption is about ·916 lb. of oil per S.H.P. hour. Then, Fuel per 24 hours$=\dfrac{4000\times\cdot9\times24}{2240}=$ 38·5 tons. (**c**) **Reciprocating Engines.**—The usual fuel consumption with oil-fired boilers is about 1 lb. of oil per I.H.P. hour, and assuming a mechanical efficiency of, say, 90 per cent., then I.H.P. = 4000 ÷ ·90 = 4444. Then, Fuel per 24 hours $=\dfrac{4444\times1\times24}{2240}=$ 47·6 tons. If coal, allow, say, 1·5 lbs. per I.H.P. hour, and proceed as shown.
178	Describe how to calculate the load on guides, main bearings, and thrust blocks.	1. *Guide Shoes.* Rule, $\dfrac{\text{Piston area}\times\text{Pressure}\times C}{P}=$ **Load on shoe.** Where R = Length of connecting rod. ,, C = ,, crank. ,, $P=\sqrt{R^2-C^2}$. 2. *Main Bearings.* Rule, $\dfrac{\text{Piston area}\times\text{Pressure}}{2}=$ **Total load** on each main bearing. 3. *Thrust Blocks.* Rule, $\dfrac{\text{Total I.H.P.}\times33000\times\cdot75}{\text{Ship speed in feet per minute}}=$ Total load on thrust. *Note.*—The effective I.H.P. on the thrust block is taken as equal to $\dfrac{75}{100}$ of the total I.H.P. *Note.*—Ship speed in feet per minute $=\dfrac{\text{Knots}\times6080}{60}$.

No.	QUESTION.	ANSWER.
179	State clearly the points of mutual agreement between heat and work.	See p. 3.
180	What is efficiency? What does it mean when referred to an engine or machine?	Efficiency means the effective work or heat obtained from a machine or engine compared with the total amount of work or heat put in. Expressed as a formula : $$\frac{\textbf{Effective work or heat}}{\textbf{Total work or heat}} = \textbf{Efficiency.}$$
181	Assuming equal thermal efficiency, cylinder bore, stroke, revolutions, and M.I.P. in each case, give the respective powers developed in (a) a 4-cycle engine; (b) a 2-cycle engine; (c) an opposed piston 2-cycle engine; and (d) a double-acting 2-cycle engine. Take, say, 100 per cent. as basis.	(a) 4-cycle engine = 100 per cent. power. (b) 2-cycle ,, = 200 ,, ,, (c) Opposed piston engine = 400 per cent. power. (d) Double-acting 2-cycle engine = 400 per cent. power.
182	Give a definition of Brake Thermal Efficiency; also show a worked out example.	By Brake Thermal Efficiency is meant the heat efficiency of the engine when referred to the B.H.P., and which will therefore be less than the Indicated Thermal Efficiency in inverse proportion to the mechanical efficiency of the engine and fuel consumption. EXAMPLE.—The fuel consumption is ·42 lb. per B.H.P. per hour : find the Brake Thermal Efficiency if the calorific value of the fuel is 18,500 B.T.U.'s per lb. Then, Efficiency $= \dfrac{33000 \times 60}{·42 \times 18500 \times 778} = ·33$, or 33 per cent.

No.	Question.	Answer.
183	Describe how to set the fuel pumps of an auxiliary Diesel engine.	Remove the governor springs, pull out the weights, and with starting handle in running position allow $\frac{4}{1000}$ in. clearance at suction valve tappet, the pump plungers to be at full stroke (out).
184	How are the roller clearances of the air suction, exhaust, and air starting valves taken?	By turning the flywheel to the mark indicating "fuel pump on bottom," and testing the clearance of each valve roller and cam at this position; the starting handle to be hard over.
185	Referring to auxiliary Diesel engines, state the causes of relief valves lifting.	(1) Blast air pressure low. (2) Levers too far back. (3) Fuel valve sticking or leaking. (4) One cylinder missing fire. (5) Fuel pump regulator rod slackened back. When blast air pressure is low the exhaust gives off black or bluish smoke, and the engine will slow down. With high blast air pressure the exhaust gives off a whitish smoke, and, due to misfiring, the speed will be unsteady, with heavy ignition knocks.
186	Referring to auxiliary Diesel engines, describe the bad effects produced by lubricating oil finding its way from the crank case past the piston rings up into the cylinder.	This trouble is usually caused by over-lubrication, and the effects are as follows :— 1. Knocking in the cylinder due to pre-ignition. 2. Choking of exhaust passages with carbon deposit. 3. Deposit of hard carbon on piston crown. 4. Excessive pressure in cylinder causing the relief valves to lift. The lubricating oil passing the piston rings acts in the manner of excessive fuel and, not being in a properly pulverised condition, leads to the effects described above. If the carbon deposits remain at a red heat, pre-ignition will take place.

No.	QUESTION.	ANSWER.
187	Describe how an auxiliary Diesel engine is started up.	In starting, the engine is first barred up to just over top centre position, and, having primed up the cylinder fuel valves by hand, the starting handle is placed in the "start" position, which admits air to the cylinder. After, say, two or three revolutions on air, the handle is then pushed over, through the "stop" position, to fuel, which has the effect of raising the starting air valve cam roller off its cam, and dropping the fuel valve cam roller on to the corresponding cam, and the engine, therefore, begins to fire. After running on fuel for a short period the fuel cam roller clearance can be slightly adjusted by means of the handle if required. This can also be done when running under conditions of reduced load. See p. 273.
188	Sketch out or describe the starting gear usually fitted to auxiliary Diesel engine sets.	The fuel valve lever and air starting valve lever are mounted eccentrically on the fulcrum shaft, and by means of a hand lever either valve can be brought into action as required, or both valve cam rollers can be raised off their cams. The starting handle has three defined positions—(1) "Start," (2) "Fuel," (3) "Stop." See p. 273.
189	Referring to auxiliary Diesel engines, what may cause the engine to refuse to start on air? Also if the engine starts on air and then runs astern?	1. Read gauges and make sure they are indicating correctly. 2. See that the starting cylinder exhaust valves have not lifted off their seats. 3. See that the starting air cylinder cranks have been turned just over their top centres. 4. See that engine is not overloaded.

No.	Question.	Answer.
190	What might be the reason for the indicator diagrams showing a reduced area after a period of service? Where would you expect to find the cause for this difference?	If after, say, a period of service running, the indicator diagrams show a diminished area, the cause may be expected to be found in the cylinder fuel valves, the pulveriser ring openings of which may have become partly choked up. This might easily happen if the oil used under service conditions was of a heavier class than that used during the trial runs.
191	Give examples of defects in oil engines, and state how these may be remedied.	See p. 381.
192	Describe or sketch out an oil film type thrust block.	See diagram to face p. 282.
193	What is the weight of 1 gal. of fresh water in British measure and in American measure?	In British measure 1 gal. fresh water = 10 lbs. In American measure 1 gal. fresh water = 8·33 lbs.
194	Sketch out the usual method of cylinder fuel cam adjustment.	

No. 444.

1, Cam keyed on to camshaft.
2, "Toe" of cam, which is separate and adjustable.
3, Liners for adjustment.
The liners (3) can be increased on one side and reduced on the other side as required, and the valve timing either advanced or retarded.

Note.—If the cam roller clearance is increased, the valve will open later and close earlier.

No.	QUESTION.	ANSWER.
195	Describe two types of piston rod crosshead —(a) solid; and (b) detachable.	

No. 445.—Solid Type Crosshead.

No. 446.—Detachable Type Crosshead.

In the *solid type* of crosshead two bolts are fitted to keep the half round brass in position on the keep as shown.

In the *built type* of crosshead the pin is divided and is forged solid with the block, the piston rod forming a taper fit and being secured by a nut below. Two bolts are required for each brass, or four bolts in all.

No.	QUESTION.	ANSWER.
196	If engine starts and there is no ignition when given fuel, state causes?	1. Investigate if valves between settling tanks and fuel pump are open. 2. Air lock in fuel pump. 3. Non-return valves on fuel delivery pipe leaking. 4. Fuel oil either too heavy or contains water.

No.	QUESTION.	ANSWER.
196	—*Continued*.	5. Fuel by-pass valves may be open. 6. Blast air too low. 7. Compression low, which may be due to dirty suction air strainer, leaky piston rings, leaky valves or valve bodies, compression clearance too great, cracked piston crown or cylinder head. 8. Engine may be braked, either due to tight bearings or propeller fouled.
197	State causes of smoky exhaust.	1. Overload. 2. Unsuitable fuel. 3. High resistance to exhaust. 4. High resistance in fuel valve pulveriser. 5. Blast too low (bad combustion). 6. Leaky fuel valve (excessive fuel ?). 7. Low compression. 8. Dirty atomiser. 9. Incorrect lift of fuel valve. 10. Late ignition (bad combustion). 11. Dirty induction strainers, which may cause knocking in the engine.

AIR COMPRESSORS

No.	QUESTION.	ANSWER.
198	Sketch out an arrangement of air compressors.	See diagram to face p. 80 ; p. 265.
199	Mention special advantages of 3-stage compressor over 2-stage compressor ; also referring to efficiency.	The 3-stage compressor admits of more efficient cooling of the compressed air ; also a smaller size of machine, and a slightly higher efficiency. See facing p. 80 ; pp. 265, 863-867.

No.	QUESTION.	ANSWER.
200	What is the usual temperature of the compressed air at discharge from the H.P. compressor inter-cooler?	The temperature of the compressed air at delivery from the H.P. compressor ranges from 86° to 110° F. See facing p. 315.
201	Why is the air compressed in two or in three compressor stages in place of in only one stage?	By compressing the air in stages the temperature can be lowered more conveniently and the moisture present deposited and extracted more effectively. The volume is also reduced. See facing p. 315.
202	What is the object of compressor inter-coolers?	Inter-coolers are employed to cool down the air after each stage of compression during which the temperature has been increased by work done on the air gas.
203	What type of compressor requires inter-coolers? How are they tested? How examined?	Compressors of two or three stage type require inter-stage coolers to extract the heat of compression at each stage. The coils are withdrawn and put under an air and water pressure of 2000 lbs. per sq. in. The coils are also examined for thinning down by water friction (erosion) or general wear, and are sometimes tested for the same by being weighed at regular intervals of, say, three months, so that loss of weight may be detected, care being taken previous to weighing that all deposits of dirt or oil are boiled out of the tubes or coils.
204	How often should the compressor valves be cleaned and reground?	Compressor valves should be taken out and reground, if possible, every six weeks.
205	What is the average percentage of the total power absorbed by air compressors?	From 8 to 10 per cent.

No.	Question.	Answer.
206	Describe how to test for a leaky compressor suction or delivery valve.	To test H.P. delivery valves, take out suction valves, turn on the air pressure, and notice if air comes out back from the air bottles. To test H.P. suction valves, take out delivery valves and replace plug on cover, then notice if pressure falls on gauge, with air pressure on.
207	How does a leaky H.P. compressor suction valve show on the M.P. and L.P. compressor gauges?	M.P. pressure much higher than usual. L.P. pressure slightly higher than usual.
208	What may cause overheating of the air compressors?	Overheating of compressors may be caused by lack of (a) lubrication; (b) insufficient water cooling; (c) leaky tubes in inter-stage coolers driving out the cooling water.
209	What kind of joints are fitted to compressor and air bottle connections?	Copper asbestos joints, copper diamond section rings, or nautilus jointing are fitted to compressor and blast air bottle connections.
210	How are the compressor cooling coils cleaned outside and inside?	Inside, by boiling out with steam or by a solution of soda. Outside, by brushing over with muriatic acid solution.
211	If moisture is present in the air, at which part of the compressor system is this got rid of?	Water present in air is deposited in the inter-cooler tubes and in the air bottles, from which it is extracted by suitable drains.
212	If the blast air was of high temperature, what might happen?	With blast air of high temperature, pre-ignition might occur at the cylinder fuel valve; the air would also be of larger volume for equal weight, and might contain moisture in suspension.

No.	QUESTION.	ANSWER.
213	Describe the construction of a steel air reservoir suitable for a Diesel engine-room, paying special attention to end plates to allow for expansion.	An air reservoir or tank is similar in construction to a Lancashire boiler. The ends are dished hemispherically for expansion allowance, and the fittings include a relief valve and a drain valve. The shell is fitted with double butt straps in the longitudinal joints. The pressure carried is about 350 lbs. 🔲 or 25 atms. See p. 80.
214	Describe fully an air reservoir. What is its use relative to the main engines? What pressure is it kept charged to, and why?	Air tanks or reservoirs are employed for the storage of low pressure or starting air. In some engines two of the main engine compressors are of the two-stage type, and are arranged to draw from the reservoirs at, say, 300 lbs. pressure, and compress up to 950 lbs. for blast air purposes. See p. 80.
215	How often should the blast air bottles be drained, and why?	Blast air bottles should be drained half-hourly, as moisture present in the blast air would lower the efficiency of combustion.
216	What attention do air bottles require, and how are they cleaned out?	Require to be drained out at regular intervals. Should be always kept charged up. Safety valves to be overhauled and tested twice a year. To be cleaned of all greasy deposits (boiling with steam) at regular intervals.
217	Why should the air bottles be drained at regular intervals?	To ensure that no water is carried into the cylinder with the blast air, and which, if present, would seriously interfere with firing and combustion. The bottles should be drained out half-hourly.
218	Why are fusible plugs fitted on starting air tanks and on blast air bottles?	Fusible plugs are fitted on air tanks and blast air bottles to prevent explosion due to expansion and increase of pressure of the contained air by external rise of temperature, which might happen should a serious fire occur in, say, the ship's oil tanks. The plugs are composed of a composition, which melts when the temperature exceeds about 200° F. See p. 80.

No.	QUESTION.	ANSWER.
219	Describe the usual construction of starting air tanks.	Air tanks are usually constructed of heavy boiler plate and are cylindrical in section, having dished-out end plates, but being of moderate diameter, longitudinal stays are omitted. The circumferential seams are double riveted, while double butt strap joints are fitted longitudinally as in cylindrical boilers. The fittings required are: Inlet valve, reducing valve, relief valve, drains, and fusible plugs. In some cases the starting air is stored up in large steel bottles placed vertically. See p. 80.
220	State the usual air pressures carried for starting and for fuel blast purposes.	Starting air pressure about 20 atmospheres, or 350 lbs. per sq. in. (4-cycle) and 600 lbs. (2-cycle). Blast air pressure about 60 atmospheres, or 950 lbs. per sq. in.
221	What should be the maximum and minimum blast air pressure allowed?	1000 lbs. per sq. in. maximum, and, say, 600 lbs. minimum.
222	What is the objection to the use of compressed oxygen for starting purposes, assuming that the air pressure supply fails?	Danger of explosion due to vapour from oil leakage and resultant rapid chemical combustion.
223	How many revolutions on starting air should be sufficient before putting the engine on fuel?	Starting from cold, and fuel pipes well charged with oil, 2 revs. If warmed up, about $\frac{1}{2}$ rev. should be found sufficient.
224	What may cause the starting air pressure to fall away?	Starting air valve or master air valve leaky. Broken valves in compressor. Shortage of starting air, which may have been used up by recent operations.

No.	Question.	Answer.
225	Give definitions of the terms "Isothermal" expansion and "Adiabatic" expansion as referred to gases; also describe how Boyle's Law and Charles's Law can be combined in calculations dealing with the expansion or compression of a gas.	By "Isothermal" expansion is meant expansion at constant temperature, which means that at a certain position of the cycle (expansion) heat must be added, and at another point (compression) heat must be taken away. Boyle's Law is based on isothermal expansion. By "Adiabatic" expansion is meant expansion carried out at the expense of the internal heat of the gas, so that at a certain point in the cycle the temperature will fall (expansion), and at another point the temperature will rise (compression). Expansion and compression of steam in actual practice partakes of each of the above conditions. In Diesel practice compression is nearly adiabatic in nature. Boyle's Law refers to the expansion of gases at constant temperature, whereas Charles's Law refers to the effects of temperature on the volume and pressure. For perfect gases, both laws can be combined as follows :— $$\frac{P_1 \times V_1}{T_1} = \frac{P_2 \times V_2}{T_2} = \text{Constant.}$$ **Where** P = Absolute pressure. T = Absolute temperature, or temperature Fahrenheit + 460°. See pp. 2, 3.
226	What are the advantages of three-stage compressors ?	Three-stage compression permits of (*a*) more effective heat extraction from the air; (*b*) keeps down the air volume; and (*c*) admits of the effective deposit of moisture at each stage of compression.
227	What is the average temperature of the air after compression, in, say, the H.P. stage of an air compressor—before cooling, also after cooling ?	At the end of final compression and before cooling, the temperature of the air averages about 300° F. After passing through the coolers the temperature falls to about 95° F. Cooling of the air induces the deposit of any moisture present, and for this reason drains are fitted on the air side of the coolers.

No.	QUESTION.	ANSWER.
228	Mention defects common to compressors and describe how these are remedied.	1, Broken valves; 2, valves sticking or carbonising; 3, broken rings. In No. 1, valves must be renewed from the spares carried. In No. 2, is often caused by inferior lubricating oils used or to excessive lubrication, the oil being carried up by the piston and thrown on to the valves. Engine requires to be stopped and valves cleaned or replaced. In No. 3, with twin-screw vessel it may not be necessary to stop the engine, as by a cross-connection from the regulating head air may be obtained from the compressor of the other engine.
229	Referring to Diesel engine practice, mention the purpose for which compressed air is employed.	Compressed air is employed for (1) starting purposes; (2) for blast injection purposes, that is, for blowing the fuel oil through the fuel valve into the cylinder; and (3) for firing and combustion purposes. Starting air pressure ranges from 300 to 450 lbs. per sq. in. Blast air pressure ranges from 600 to 950 lbs. per sq. in., and varies with the engine speed. Firing pressure (compression) air ranges from about 450 to 500 lbs. per sq. in.
230	What danger attaches to a very low blast air pressure?	If the blast air pressure falls below the compressed air pressure within the cylinder, the fuel would blow back when the fuel valve opened and ignite above the valve, with attendant danger of a serious explosion, which may result in the complete destruction of the valve casing and valve gear.
231	Describe a Diesel type air compressor. What defects would you expect to find after a long voyage? Describe how to remedy the defects.	See pp. 369-377.

No.	QUESTION.	ANSWER.
232	Referring to the compression of air for fuel injection purposes, why is isothermal compression desirable, and how is this obtained in practice?	In Diesel engine cylinders the compression of the suction air or scavenge air should be carried out under adiabatic conditions, so that the necessary temperature rise required for ignition and firing will be obtained. In the air compressors the case is different, and it is advisable to keep down the temperature of the air to about 95° F., with the object of preventing pre-ignition. It is therefore desirable that the compression of the air should be completed under isothermal conditions, that is, at constant temperature, and to obtain this result approximately, the compressor cylinders are water jacketed, and stage inter-coolers are also fitted to extract the heat at each compression stage.
233	When 4-cycle engines are arranged for supercharging, how is air pressure obtained?	By the use of electrically-driven rotary blowers, or if steam is available, by turbo-blowers, that is rotary blowers driven by small high speed turbines. The supercharge air pressure ranges from about 3 lbs. to 7 lbs. per square inch above atmospheric pressure, and can be raised to suit the power output required.
234	Describe briefly the construction of a scavenge pump and connections.	The scavenge pump cylinder is of cast iron and the valves of sheet steel, with light springs to hold them in position on the grids. The valves are also fitted with a perforated plate on top, to which the springs are fitted. Air is drawn from the atmosphere and delivered at a pressure of 2 or 3 lbs. per sq. in. to an air trunk or receiver fitted round the cylinders, the trunk being in connection with the scavenge ports in the cylinder liner. See pp. 193-217.
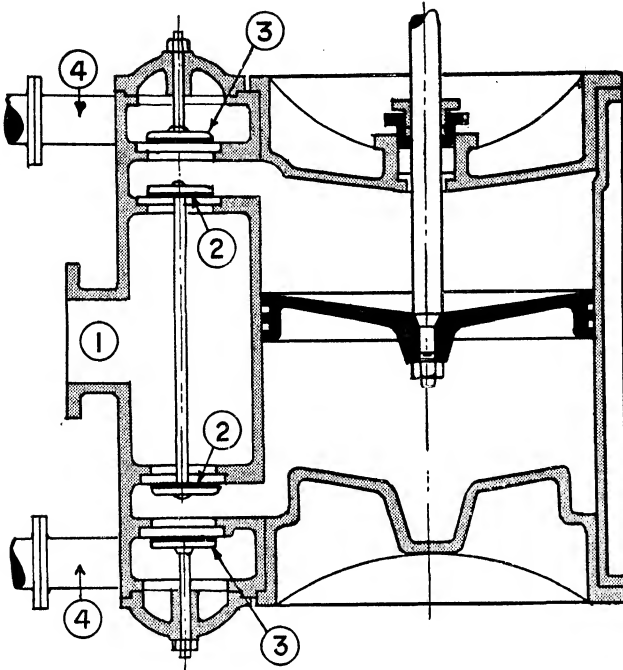
No. 447.—D.A. Scavenge Air Pump for 2-Cycle Engine.
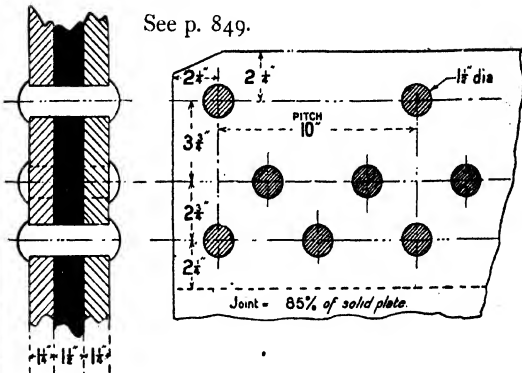
May be lever driven or crank driven; if the latter, the pump would then be inverted in position.

1, An inlet from atmosphere.

2, 2, Air suction valves.

3, 3, Air delivery valves.

4, 4, Delivery air, at about $1\frac{3}{4}$ lbs. pressure from pump ends to common branch of scavenge air trunk of cylinders. The valves are of the thin plate disc type.

Note.—The capacity of the scavenge air pump is often designed to be equal to about 1·4 times the combined cylinder stroke volume of the engine.

Example.—The engine consists of 6 cylinders, each 25 in. diameter, and stroke 40 in., the scavenge pump stroke also being 40 in.

Then,   Diameter of pump $= \sqrt{\dfrac{25^2 \times \text{\st{4}} \times \text{\st{40''}} \times 6 \times 1\cdot4}{\text{\st{40}} \times \text{\st{6}}}} = 72\cdot4''$.

No.	QUESTION.	ANSWER.
235	Describe a double butt strap joint. Where is it placed, and why? Sketch out the joint with approximate dimensions.	See p. 849.
236	Describe a scavenge pump for a 2-stroke engine.	See pp. 193, 217, 611.
237	Why is compressed air necessary, also economical in use? How is high pressure obtained in hot-bulb engines?	To obtain ignition and combustion, air of high pressure is required. When the suction air is compressed on the upstroke to a pressure of, say, 500 lbs., this temperature rises to somewhere about 1100° F., because work has been done on the air gas. This high temperature permits of ignition taking place when the fuel is blown into the cylinder through the fuel valve. In hot-bulb engines high pressure and temperature is obtained by the combined effects of moderate compression (about 200 lbs.) and the dull red heat of the bulb in the cylinder head.

SEMI-DIESEL ENGINES

No.	QUESTION.	ANSWER.
238	Describe a semi-Diesel engine. Explain its action.	When the piston is at the end of its downward stroke and moving up towards the cylinder head, the necessary air for combustion is drawn in through the air valves into the enclosed crank chamber, and at the same time the air in the combustion chamber head is being compressed. When the piston has reached the top of its stroke, a minute amount of crude oil is sprayed into the vaporiser, and thus an explosive mix-

No.	QUESTION.	ANSWER.
238	—*Continued.*	ture is formed and immediately fired by the heat of the bulb, driving the piston downwards. During this downward stroke of the piston the air in the crank chamber is compressed, and as the piston nears the end of its stroke, the exhaust port is uncovered, and immediately afterwards the inlet air port. The burnt gases escape by the exhaust port, whilst the compressed air in the crank chamber entering the cylinder by the port completes the scavenging work and furnishes the cylinder with air necessary for the next fuel charge. The piston is now on its upward stroke again, and the cycle is completed. ### Cycle of Operations. **Downstroke.** *Above Piston.*—Ignition of fuel, combustion, expansion of gases, uncovering of exhaust and scavenge ports near bottom centre. *Under Piston.*—Compression of crank case suction air to about 3 lbs. pressure per □. **Upstroke.** *Above Piston.*—Compression of scavenge air to about 200 lbs. pressure per □. Injection of fuel near top centre. *Under Piston.*—Suction air enters crank case through inlet valves. Firing is obtained by the combined effects of moderate compression and the hot bulb or uncooled part of the cylinder head, against which the liquid fuel is injected by the fuel pump.
239	Explain the difference between an "explosive" engine and an "internal combustion" engine.	In an "explosive" engine, combustion takes place under conditions of "constant volume," with the result that a sudden increase of pressure occurs at ignition point when the fuel is admitted. In an internal combustion engine (Diesel), combustion takes place under conditions of "constant pressure," so that at the firing point the pressure increases only slightly, as the increase of volume tends to keep the pressure nearly constant during fuel admission.

No.	QUESTION.	ANSWER.
240	How is firing of the charge carried out in the case of a hot-bulb engine?	By means of moderate compression (say 250 lbs.) combined with the hot bulb which admits of ignition and firing taking place.
241	Explain why water is sometimes admitted to a hot-bulb oil engine cylinder.	See pp. 41, 455.
242	Describe how a Bolinder type hot-bulb engine is started up and reversed.	See pp. 461, 466, 479 ; facing p. 480.
243	Describe the action of a hot-bulb engine. Explain clearly how it is reversed.	See pp. 467, 476, 479 ; facing p. 480.
244	Referring to semi-Diesel H.B. engines, describe the effects obtained by injecting water into the cylinder. Why is this done? Sketch out a diagram card and show the effects of water injection.	See pp. 41, 455. Diagram will show of less height, but will be greater in width. Reduces the temperature of the hot bulb, and reduces knocking.
245	Draw diagrams for petrol, 2-stroke heavy explosion, and Diesel 4-stroke engines, and give respective compression and explosion pressures and temperatures.	See pp. 288, 289, 473, 505, 622 (No. 285).
246	When a 2-cycle explosive engine is coupled to a dynamo running at light load, trouble is sometimes found in keeping the engine running. Describe how this defect is remedied.	See pp. 41, 455.

No.	QUESTION.	ANSWER.
247	Describe how a heavy 2-stroke explosive engine is reversed.	See p. 478 ; facing p. 480.
248	What may cause over-heating of the bulb ?	Over-heating of the bulb may be caused by (a) inattention to the cooling arrangements either by the observation doors having been left shut and thus preventing the circulation of cooling air round the bulb ; or, (b) if the bulb is cooled by water, the supply being insufficient for the purpose.
249	What may cause the bulb to remain constantly at high temperature ?	This condition may arise through the bulb metal becoming reduced in thickness by scaling action.
250	State the cause of thinning of the bulb.	If the bulb is maintained at an excessive temperature the metal flakes or scales off when cooling down occurs, and therefore gradual thinning of the bulb will take place.
251	Give the causes of irregular running in hot-bulb engines.	1. Defective governor spring. 2. Defective fuel injector. 3. Defective scavenge air supply. 4. Defective fuel pump valves. 5. Excessive lubricating oil supply. 6. Bulb temperature wrong.
252	How can the faults mentioned be observed ?	Notice if one fuel pump is running with more misses than the others, if so, the governor spring will most likely be defective. The cylinder fuel injectors should be examined to see that all are spraying properly and on to the correct portion of the bulb. Examine the main bearings for leakage of scavenge air, also leakage of lubricating oil which may also cause hot bearings. See if crank case drain cock is open or closed. If the fuel pump delivery valve is at fault the bulb of that cylinder will cool down and the other heat up. The engine may also run away on lubricating oil which has passed up the scavenge transfer port to the cylinder. Notice if one bulb is not hotter than the others.

No.	QUESTION.	ANSWER.
253	When no forced lubrication system is fitted, how is lubrication of the crosshead pin provided for in the case of hot-bulb engines, with trunk pistons?	The crosshead pin is bored out both longitudinally and radially, and by means of a "dip" tube and non-return ball valve secured to the pin, oil is supplied from a fixed containing vessel. On each downstroke the tube end dips into the oil which lifts the ball valve and fills up the tube, the ball dropping back again into position on the upstroke. The oil is thus carried up to the crosshead pin, and entering at a radial hole to the centre, escapes by another radial hole to lubricate the bearing.
254	How are hot-bulb engines governed?	Some types are controlled by means of a hit and miss governor, others by the quantity method.
255	Describe the systems of governing mentioned in answer to last question.	Hit and miss governing, so called because the fuel pump sometimes receives a hit and injection takes place, while sometimes it is missed when no injection takes place. This action is usually managed by having two different levels on the fuel pump table joined by a small radius. If the speed of the engine is excessive when the pecker piece comes to the radius instead of rising to the higher level steadily, it is thrown up violently and so misses the pump; should, however, the speed be correct, then it rises to the higher level steadily and hits the fuel pump nose, driving the fuel pump before it and so giving an injection. The action of the radius to throw up the pecker piece is resisted by the governor spring; should the spring pressure be heavy the speed of the engine will rise until at the correct speed the misses start to take place and the engine will continue to run at the prearranged speed. The quantity governor operates on the centrifugal weight system, the action being that as the position of the weight increases radially it acts directly on the suction cam of the fuel pump and reduces the effective stroke of the pump plunger. The suction cam is of bevelled section and the delivery cam of square section.
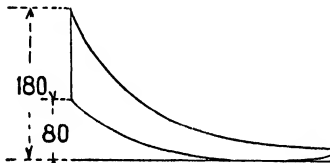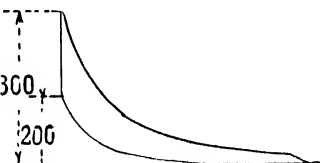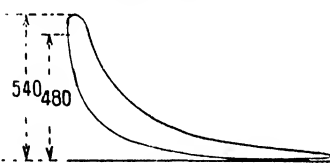
No.	QUESTION.	ANSWER.
256	What is the object of crank case drains?	To enable the surplus lubricating oil to be drained off, as, if it accumulates, the engine may tend to run away on lubricating oil.
257	How may starting air be lost?	1. By the starting valve sticking. 2. By keeping the starting valve open for too long a period when starting up.
258	How is air retained in the crank case at a pressure?	On the upstroke atmospheric air is drawn into the case through the large suction valves, and on the downstroke the valves close and the air is compressed to a pressure of about 3 lbs. $\boxed{n}$. The air is prevented from finding its way out of the case along the shaft by means of two rings fitted to the shaft and revolving with it, the face of each ring bearing up against the machined crank case wall and kept in close contact with it by means of small springs. See pp. 458, 463.
259	Give the probable causes of trouble in the starting up of hot-bulb engines.	1. Bulbs not hot enough. 2. Injectors not spraying correctly. 3. If started by means of a hot plug in the cylinder head this fitting may become carbonised up. The bulb should be brought to a dull red heat before starting is attempted. The cylinder injectors should project a solid jet of oil directly against the hot spot, without deflection in any other direction whatever.
260	What arrangements are provided for running on light and heavy loads?	For light loads the bulb can usually be covered over with a hood to prevent the circulation of air, and in this way the temperature can be maintained at a maximum. In some cases the direction of the oil jet can be altered so that it impinges at a different point on the bulb, according to the running load. For heavy loads air is allowed to circulate freely around the bulb, and in some cases a water injection is also employed. The foregoing are additional to the usual governor control of the fuel supply.

No.	QUESTION.	ANSWER.
261	What is the usual cause for choked blow lamp coils?	Opening needle valve fuel supply to lamp before the coils have been properly heated.
262	What is the average fuel pump stroke for hot-bulb engine?	From 2·5 mm. to 5 mm., according to horse power.
263	What is the usual cause for blow lamps which have been properly heated "jetting" or refusing to burn properly?	Nipple too large. This has probably been enlarged through constant pricking with the nipple cleaner.
264	What care of fuel pumps has to be taken with engines fitted with hit and miss governor?	See that the nose piece of fuel pump and also fuel pump pecker piece are not rounded off; these should be dead square to each other, have sharp edges, and each can be bevelled or undercut slightly.
265	What part of the force feed lubricators are likely to give trouble first?	The ratchet pawls and pawl springs.
266	Why is ebonite or lignum vitæ used on the governor gear of some hit and miss governed engines?	Because the small curve on the governor table would be rapidly worn if brass or any other metal were used, and this would upset the governor action.
267	Should an engine run away on lubricating oil, what would you do?	1. Cut out fuel pumps. 2. Force open and keep open crank case suction valves.
268	On being told to start an engine which has lain idle for some time, what would you look at before attempting to start?	1. See that there is fuel in fuel tank. 2. Withdraw injection nipples and see that fuel pumps deliver fuel to nipples, and that no air is in system. 3. With fuel pumps out of action bar round engine to see all is clear. 4. See circulating water valve is open. 5. See starting valve is free and seating properly.

No.	QUESTION.	ANSWER.
269	You have heated up bulbs properly and made a misstart, the engine being in good order, what would you do now?	1. Cut out fuel pumps. 2. Bar engine round to starting position. 3. Let fuel pump into action again and try once more.
270	How does a hot-bulb engine recharge the air bottles after starting?	By means of the starting valve which is spring loaded. When the engine is running, to recharge the bottles, slack back the screw-down pin on the valve and allow the valve to work outwardly when the explosion takes place and be reseated by the spring. In this way the bottles are recharged by the products of combustion and *not* with pure air.
271	What precaution must be taken with the charging up pipe of an H.B. engine?	It must never be led through bilges and should not be near oil pipes, as this pipe gets extremely hot when charging up air bottles.
272	If the bottom end of a 2-cycle engine were to run out, would you be able to detect it while the engine was running?	The engine in which the bottom end had run would not have the correct compression, and therefore the bulb would probably gradually get cold, but no knock would develop and therefore it would be difficult to say at once that the bottom end had run.
273	The lubricator is not working properly. What is the probable cause?	The pawl has probably worn, and now refuses to catch and drive the ratchet wheel. Remedy, undercut the pawl until it again catches the wheel.
274	With a new engine, how would you be sure it was getting lubricating oil?	Disconnect the lubricating pipe nipples on the engine. Work the lubricator until oil comes from each pipe, then couple up again and give several more strokes to the lubricator to ensure the supply reaching each bearing and the cylinder walls.
275	How do you judge if the temperature of the bottom end is right?	By opening the crank case drain valve and feeling the temperature of the air which blows out.

No.	QUESTION.	ANSWER.
276	Should white metal of the bottom end run out, what would be most important before trying to run again?	See that the oil hole drilled in the crankshaft is perfectly clear, as probably some white metal would be lodged in this and allow no oil to reach the new bearing.
277	What is the use of the throttle valve fitted in some scavenge transfer ports?	To enable the engine to run with light loads for a considerable period.
278	How does it function?	It prevents the transfer of cold air from the crank case to the bulb and reduces the resultant cooling effect.
279	How is the bottom end and gudgeon pin of a hot-bulb engine usually lubricated?	By a banjo ring lubricator. The pressure lubricator delivers the oil to an inside ring, which revolves with the crankshaft. There is a hole in the crank web and crankpin. Centrifugal force sends the oil into these holes and so to the journal. The gudgeon pin is bored out about two-thirds of its length with a fairly large hole, there is also a small radial hole bored from the outside to connect up with the large central hole, and within the large hole a spring is fitted which forces out the brass scraper piece and keeps it in close contact with the cylinder wall. The brass scraper piece is arranged with a semicircular head and the gudgeon pin is recessed to allow this piece to lie close against it, while the head piece conforms to the piston contour. A brass extension on the head piece fits into the large hole in the gudgeon pin and a small hole through this piece which does not extend to the outside of the head piece. As the piston rises, oil is scraped off the cylinder wall by the head piece, passes through the small hole in the brass into the large hole in the gudgeon pin and so reaches the surface by way of the small radial connecting hole in the pin. See pp. 458, 459, 463.

No.	QUESTION.	ANSWER.
280	Why is a fuel oil filter used ?	Owing to the small size of the hole in the injector nipple it is most important that the oil should be free from anything which might choke up the nipple.
281	State the effects obtained by scavenging in hot - bulb semi-Diesel engines. Show by a sketch how scavenging is carried out.	Scavenge air of about 3 lbs. pressure is employed to clear the cylinder of the exhaust gases, and at the same time refill it with clean air ready for the following compression stroke. A deflector is cast on the piston crown, which acts to direct the air flow into, and the exhaust gases out of, the cylinder. See pp. 468, 472, 476.
282	Describe how a Bolinder type semi-Diesel engine is reversed.	The engine cylinder is fitted with both a main fuel pump and an auxiliary fuel pump, the latter being employed for reversing purposes only, reversal of motion being obtained on the principle of pre-ignition. To change from, say, ahead to astern running, the engine speed is first reduced by hand control of the fuel supply, and a friction clutch tightened up by pulling the clutch lever. This has the effect of raising a large bell crank, the reciprocating motion of which operates the respective fuel pump plungers. The result obtained is to put out of action the main fuel pump and put into action the auxiliary fuel pump, which latter injects a charge of fuel into the cylinder when the piston is at about half-stroke position and moving up. The firing obtained by this pre-ignition checks the piston on its upward travel, and forcing it downwards, reverses the direction of shaft rotation. Finally, when reversal takes place the clutch brings back the bell crank, which at once assumes its former position, with the result that the engine again commences to fire at the top centre position, and continues doing so. See p. 478 ; facing p. 480.

No.	Question.	Answer.
283	How can the compression of a paraffin or petrol engine be tested?	Take out the test cock on the cylinder cover, and fit in its place a pressure gauge; then turn engine round by hand, and note the pressure registered, which should be about 60 or 80 lbs. per ☐.
284	State the usual compression pressures obtaining in petrol, paraffin, hot-bulb, and Diesel engines.	For petrol engines the average compression pressure is about 80 lbs. ☐ For paraffin engines ,, 80 ,, For hot-bulb engines ,, 200 ,, For Diesel engines ,, 480 ,,
285	Sketch out diagrams from petrol, paraffin, hot bulb, and Diesel engines. Also give the average maximum pressure and mean effective pressure for each type, together with the approximate temperatures.	180 80 **Petrol and Paraffin.** 300 200 **Hot Bulb.** 540 480 **Diesel.**

	Petrol.	Paraffin.	Hot Bulb.	Diesel.
Max. pressure	180 lbs.	160 lbs.	300 lbs.	550 lbs.
Mean effective pressure	50 lbs.	40 lbs.	60 lbs.	92 lbs.

The temperatures obtained range from about 700° F. to 1100° F.

No.	QUESTION.	ANSWER.
285	Describe how a petrol oil motor is started up, also how a hot-bulb or semi-Diesel engine is started up.	See p. 490. Hot-bulb engines are started up as follows :— 1. Apply hand blow lamp to bulb until a dull red heat is obtained. 2. Have engine barred up to just over top centre. 3. Give a starting injection of oil by hand trigger. In the case of larger power engines open the starting air valve to give the initial impulse, then cut out the air and put in the fuel.
287	What is the average fuel valve timing for a hot-bulb semi-Diesel engine?	The fuel injector of a hot-bulb engine opens about 30° to 45° before the top centre position, and closes from 3° to 5° before or after top centre position. Combustion will therefore take place under conditions of constant volume.
288	Describe how a paraffin motor is started and reversed.	See pp. 498, 500.
289	Describe a motor launch engine. Explain how it is started.	See p. 490. A launch petrol motor is started up by first having the engine declutched, then flooding the carburetter and, cranking round by hand, firing should then take place. Before attempting a start it should be seen that the petrol supply is opened up and the spark switch in the "on" position.
290	Steam engines are governed by quantity: describe how petrol and paraffin engines are governed.	Petrol and paraffin engines are usually governed by quantity, but in some cases by quality of the mixture. When governed by quality the amount of petrol or paraffin is reduced and the air supply increased in proportion, so that the mixture is weakened when running at low powers.

No.	QUESTION.	ANSWER.
291	Name the types of internal combustion engines which are fitted respectively with carburetters, vaporisers, and atomisers; also name the fuel used for each. Also, describe the various ignition systems as employed in petrol engines, semi-Diesel engines, and full Diesel engines.	Petrol engines are fitted with carburetters. Paraffin ,, ,, vaporisers. Diesel ,, ,, atomisers. In petrol motors the gas or charge is prepared in the carburetter, and consists of air and petrol vapour mixed in the proportion of about 10 or 12 air to one of petrol. In paraffin engines vaporiser tubes or coils are required to heat up the paraffin which, being of a heavier nature than petrol, will not vaporise from cold unless heated. The tubes of the vaporiser contain either the jacket cooling discharge water or hot gases from the exhaust. With either paraffin or hot-bulb engines a hand blow lamp requires to be first applied in starting up from cold. Diesel engines use heavy oil which is atomised in the cylinder spray valve, either by high fuel pressure (solid injection) or by high blast air injection pressure. Petrol and paraffin engines are fitted with electric spark ignition systems, the necessary current being supplied when running by means of a small dynamo known as a "Magneto." In starting up from cold, however, a battery is required to obtain the initial sparks. Semi-Diesel or hot-bulb engines obtain ignition by the combined effects of the heat of low compression (about 200 lbs.) and an uncooled portion of the cylinder head, called the hot bulb. The liquid fuel from the pump is injected directly against the heated part of the cylinder cover, with the result that ignition, firing, and combustion are brought about. In full Diesel engines ignition is obtained entirely by means of the high temperature (1100° F.) of the compressed air (500 lbs.) in the cylinder, no spark or hot bulb being necessary.

No.	QUESTION.	ANSWER.
292	Describe how to test a paraffin or Diesel engine for reduced compression. How would reduced compression affect the running of the engine?	A petrol or paraffin engine of low power can be tested for compression by cranking up by hand and observing the resistance obtained, or by screwing a pressure gauge into the cover and observing the compression registered when cranking by hand. For large power engines of the Diesel type, compression is usually tested by shutting off the fuel from the cylinders, one at a time, and taking off an air compression diagram, which can then be measured by scale and the compression pressure noted. Reduced compression will cause the power developed to fall off, will lower the efficiency, and make the engine troublesome to start. Misfiring might also occur when running.
293	State the difference in the construction of the vaporiser (carburetter) of a petrol engine and of a paraffin engine.	A paraffin engine vaporiser is fitted with exhaust gas heating tubes to promote vaporisation of the fuel, which is of a heavier nature than petrol. See pp. 507, 512.

FUEL OILS AND LUBRICATING OILS

No.	QUESTION.	ANSWER.
294	Referring to fuel oil, give clear definitions of "open flash point," "close flash point," "fire point," and "viscosity."	See pp. 419, 426, 432, 435, 437.
295	How can the viscosity of an oil be reduced?	By heating.
296	How is the viscosity determined?	See p. 437.

No.	QUESTION.	ANSWER.
297	Describe how to test an oil for "open flash point," "close flash point," and "fire point."	See pp. 419, 425, 428, 432.
298	What is the "close flash point" allowed by the Board of Trade and Lloyd's Survey?	The "close flash point" of oil should not be lower than 150° F.
299	State the average composition of fuel oil as used in Diesel engine practice.	See p. 417.
300	State the objections to the presence of (1) water in oil; (2) sulphur in oil.	(1) Water in oil would reduce the efficiency, as combustion would be adversely affected; (2) sulphur in oil tends to induce pitting in the exhaust valves and seats.
301	Compare the heat value per pound of average coal and per pound of average fuel oil.	1 lb. average coal contains about 14000 B.T.U.'s; 1 lb. average oil contains about 18500 B.T.U.'s.
302	Give a rule for the calculation of the heat value per pound of fuel (oil or coal).	See p. 415.
303	Apply the rule (Question 302) to find the B.T.U. value per pound of fuel oil of the following composition :— Carbon, 84.5 per cent.; hydrogen, 11.5 per cent.; oxygen, 3 per cent.; sulphur, moisture, nitrogen, etc., 1 per cent.	See p. 415. $$C = \frac{84.5}{100} = .845$$ $$H = \frac{11.5}{100} = .115$$ $$O = \frac{3}{100} = .03$$ Then, $14500 \times .845 + 62100 \times \left(.115 - \frac{.03}{8}\right) =$ 19161 B.T.U. Ans.

No.	QUESTION.	ANSWER.
304	Describe the construction and application of the Baumé hydrometer for taking the specific gravity of fuel oils.	See pp. 430, 431
305	Convert 30° Baumé into ordinary specific gravity.	See p. 430. Then, $\dfrac{140}{130+30} = \cdot 875.$ **Ans.**
306	Convert ·88 specific gravity into degrees Baumé.	See p. 431. Then, $\left(\dfrac{140}{\cdot 88}\right) - 130 = 28.$ **Ans.**
307	State the number of cubic feet of tank capacity allowed per ton of fuel oil.	About 38 to 39 cub. ft. per ton.
308	A tank contains 80 tons of oil at a temperature of 60°, and 38 cub. ft. are allowed per ton. Find the space occupied by the oil if the temperature rises to 86°.	Space occupied at 60° temp. $= 80 \times 38$ $= 3040$ cub. ft. Expansion $= 3040 \times (86 - 60) \times \cdot 00034$ $= 26 \cdot 87$ cub. ft. Space now required $= 3040 + 26 \cdot 87$ $= 3066 \cdot 8$ cub. ft.
309	What is the weight in pounds per cubic foot of an oil, the specific gravity of which is ·85?	$62 \cdot 5 \times \cdot 85 = 53 \cdot 125$ lbs. *Note.* — 62·5 lbs. = 1 cub. ft. fresh water.
310	How many pounds of oil of ·81 specific gravity will be contained in 1 gal.?	$10 \times \cdot 81 = 8 \cdot 1$ lbs. *Note.* — 10 lbs. = 1 gal. fresh water.
311	Give definitions of "one B.T.U." and "one Calorie."	One B.T.U. is equal to 778 ft.-lbs. of work, and is the heat (or work) required to raise the temperature of 1 lb. of water at 40° F. one degree in temperature. One Calorie is the heat required to raise 1 kg. of water from 0° to 1° C.

No.	QUESTION.	ANSWER.
312	Referring to oil tanks, how is expansion of the oil allowed for? How is the vapour got rid of? What is the object of settling tanks, and how are these tanks arranged? How is the depth of oil in the tanks measured?	*Expansion of oil in tanks is allowed for by expansion trunks or by the volume of the vapour escape pipes. The tanks should never be quite filled up, so that expansion may be allowed for. Settling tanks are fitted with a steam heating coil, to induce rapid separation of the oil from any water present, and so extract the latter. The depth of oil in tanks can be measured by sounding rods, or, in the case of settling tanks, by glass oil gauges which are calibrated for quantity contained.*
313	What is the difference between Shale oil and Mexican oil?	See pp. 411, 417, 424.
314	Give the names of oils in general use for Diesel practice.	Mexican, Californian, Russian, Shale.
315	Show the calculation which gives the oil consumption per B.H.P. per hour, and state what this averages in good practice.	$$\frac{\text{Oil used per 24 hours in lbs.}}{\text{B.H.P.} \times 24} = \text{lbs. per B.H.P. per hour.}$$ The fuel consumption ranges from about ·4 lb. to ·43 lb. per B.H.P. per hour, and from ·32 lb. to ·344 lb. per I.H.P. per hour.
316	State the average number of barrels of oil per ton.	About 6·5 to 7 barrels per ton.
317	How is petroleum understood to form in the earth?	See p. 410.
318	What is the difference between mineral, animal, and vegetable oil?	Mineral oils are free from acid, while animal and vegetable oils contain corrosive acids.
319	Name the principal sources of supply for fuel oil.	America, Russia, Mexico, Borneo, etc.

No.	Question.	Answer.
320	What is known by the term "fixed oils"?	Animal oil and vegetable oil are known as "fixed" oils, as these oils do not volatilise on the application of heat without decomposition taking place. Also contain corrosive acids.
321	What is the meaning of "distillation" as referred to crude oils?	See pp. 410, 411, 412.
322	How are oils "refined"?	See p. 410.
323	A pound of oil contains 18500 B.T.U.: express this in foot-lbs. of work energy.	Then, $18500 \times 778 = 14393000$ ft.-lbs.
324	Describe flash point test, and give flash point of oils suitable for petrol, paraffin, and Diesel engines.	See pp. 410, 434.
325	State the average consumption of fuel per B.H.P. per hour for Diesel engines, hot-bulb engines, and petrol engines.	Full Diesel engines, ·42 lb. Hot-bulb engines, ·5 lb. Petrol engines, ·6 to ·7 lb.
326	How can the presence of sulphur in the fuel oil be detected?	Sulphur in oil can be detected by the yellowish tinge in the smoke at exhaust (funnel); also by smell.
327	Give a specification of a good fuel oil suitable for Diesel engine purposes.	Fuel oil suitable for Diesel engines :— Sp. gr. - - - ·915 Flash point - - 200° B.T.U. - - - 19000 Carbon - - - 85 per cent. Hydrogen - - 12 ,, Oxygen - - - 2 ,, Sulphur ⎫ - - Asphaltum ⎬ - - 1 ,, Water ⎭ - - Ash - -

No.	QUESTION.	ANSWER.
328	State the maximum percentage of water and of sulphur you would accept in a fuel oil sample.	Maximum percentage sulphur allowed should not exceed : $S = 1\frac{1}{2}$ per cent. and water $= \cdot05$ per cent.
329	Give the constituents, flash point, and calorific values of the different fuels used in internal combustion engines.	See pp. 409, 415-417.
330	State the calorific value of a heavy Diesel engine oil. Detail how the heat is utilised in the engine.	About 18500 B.T.U. per lb. See pp. 29, 241.
331	Describe how the close flash point of oil is taken.	See pp. 432-435.
332	What is the fuel consumption per B.H.P. hour in a 4-stroke Diesel?	About ·4 lb. per B.H.P. hour.
	At what rate is the consumption altered by going at three-quarter and half speed?	At three-quarter power about ·51 lb., and at half power about ·55 lb.
333	What is meant by calorific value of fuels?	See p. 425.
	State meaning of number of thermal units per pound.	
	Give calorific value of coal.	Coal $= 14000$ B.T.U. per lb.
	Give calorific value of paraffin.	Paraffin $= 20000$ B.T.U. per lb.
	Give calorific value of crude oil.	Crude oil $= 19500$ B.T.U. per lb.
	Give calorific value of heavy residual oil.	Residual oil $= 18500$ B.T.U. per lb.
	Give calorific value of producer gas.	Producer gas $= 180$ B.T.U. per cub. ft.

No.	QUESTION.	ANSWER.
334	Why is more fuel used per B.H.P. per hour when running at half speed than when running at full speed?	As the frictional losses remain nearly constant at all speeds the fuel per B.H.P. will work out more at low powers than at high powers. See p. 51.
335	Give a complete specification for good fuel oil.	Flash point, not lower than 150° F. Specific gravity at 60° F., ·94. Viscosity at 175° F. $\begin{cases} 53 \text{ Redwood No. 2.} \\ 68 \text{ Saybolt.} \\ 2 \cdot 1° \text{ Engler.} \end{cases}$ Carbon, 85 per cent. Hydrogen, 12 per cent. Oxygen, 2 per cent. Impurities, 1 per cent. Calorific value, 17600 B.T.U. (lowest).
336	What is gas oil?	Gas oil is obtained by the distillation of petroleum. It gives out a strong light and is chiefly used for illuminating purposes. See p. 410.
337	What is naphtha?	Mineral naphtha consists chiefly of hydrocarbons, paraffins, and olefines. Naphtha is also obtained from coal tar, and from wood by distillation processes.
338	What is solar oil?	Solar oil is a refined grade of oil obtained by the distillation of petroleum. It possesses a low flash point (184° F.), and is therefore suitable for the running of low-power engines. See p. 412.
339	Give a clear definition of combustion.	Combustion is a chemical process and consists of the combination of carbon and hydrogen of fuel with oxygen of atmospheric air, with the evolution of heat. See p. 426.
340	Mention the products of complete combustion and of incomplete combustion.	Complete combustion produces CO_2 and H_2O. Incomplete combustion produces CO and smoke. *Note.*—Water vapour=H_2O. CO_2=Carbonic acid gas. CO=Carbonic oxide gas.

No.	QUESTION.	ANSWER.
341	If the fuel oil is changed from a light to a heavier oil, what adjustments should be made?	Increase the lift of the fuel valves; also remove, say, one pulveriser ring to reduce the resistance. It may also be found necessary to slightly raise the blast air pressure.
342	How can the presence of water in oil be detected?	Mix a sample of the oil in a bottle with water, and after shaking, notice if the mixture emulsifies and appears like white coffee. If so, the oil should be analysed.
343	Describe how to test if water is present in fuel oil.	To test for the presence of fuel oil, "water finder" papers are usually employed. These are brown in colour, but when immersed in oil any water present bleaches the paper to a white colour. The paper strips are attached to a sounding rod or stick.
344	What kind of oil is most suitable for lubrication purposes?	See pp. 442, 443, 444.
345	What should the flash point be for good lubricating oil?	About 400° F. or higher.
346	Is it advisable to pass the lubricating oil through filters? and why?	Yes, the oil should always be passed through filters to remove any impurities which may be present, otherwise heating of bearings may follow.
347	What should the consumption of lubricating oil average per 1000 B.H.P. per hour under good working conditions?	About 2 lbs. per hour per 1000 B.H.P. represents fair practice, or, say, about $4\frac{1}{2}$ gals. per day for each 1000 B.H.P. developed.
348	State the special requirements of lubricating oil for use in Diesel engines.	See pp. 442, 443, 444.

No.	QUESTION.	ANSWER.
349	Mention the pressure at which the forced lubrication system should be run.	Forced lubrication pressure = 10 lbs. to 14 lbs. per sq. in.
350	State the specific gravity and viscosity of good lubricating oil, also the close flash point.	Specific gravity, ·9 to ·92. Viscosity at 122° F. $\begin{cases} 5° \text{ to } 6° \text{ Engler for} \\ \text{forced lubrication.} \end{cases}$ Flash point, 460° F. Setting point, 14° F.
351	If the flash point of cylinder lubricating oil is given as, say, 400° F. under atmospheric pressure, how will this apply when the oil is under a cylinder pressure of, say, 500 lbs.?	If the ordinary flash point of lubricating oil is taken as, say, 400° F. under atmospheric pressure, the flash point may be expected to be much higher when the oil is under a pressure of 500 lbs. As, however, the maximum temperature of cylinder liner walls is seldom in excess of about 400° F., it follows that the oil should be quite efficient under running conditions and be in no danger of flashing.
352	Mention the properties of a good mineral oil for internal lubrication.	Should possess high flash point, high evaporation point, and be free from corrosive acids. Should retain its viscosity through a range of temperatures and be free of asphalt deposits. Sp. gr. at 60° F. = ·9. Flash point open = 400° F. Viscosity at 70° F. . = 750 seconds. ,, 120° F. = 140 ,, Setting point (solidifies) = 30° F.
353	What is the objection to the presence of hydrocarbon in lubricating oil for compressor use?	Under high temperatures hydrocarbons are apt to decompose ("crack") and give off oils of lighter quality; the vapours produced from which may be the cause of explosions in the compressor cylinder. The conditions for ignition are, it should be noted, favourable, as oxygen (atmospheric air) and heat are both present. For the foregoing reasons oil-wiping rings should be fitted on the compressor pistons to keep out oil.

No.	QUESTION.	ANSWER.
354	Describe a system of lubrication for the various parts of an oil engine.	In the gravity system of forced lubrication, the lubricating pumps draw the oil from the crank case where it has drained. After passing through the bearings, cooling and filtering is carried out, the oil being then discharged up to the overhead supply tanks, which may be placed at a level of, say, 25 ft. above the bearings. The oil then falls by gravity to the bearings at a pressure of from 8 to 14 lbs. per sq. in. At the main bearings, holes of about $1\frac{1}{4}$ in. diameter are bored through the centre of the shaft, together with a circumferential groove having a series of radial holes through which the oil enters the central hole, and, passing up a bored-out passage in the crank web, enters a similar opening in the crankpin, which again, like the shaft, is supplied with a circumferential groove and radial openings for oil flow. The oil, after lubricating in turn the main bearings and bottom ends, usually passes up a hole bored in the centre of the connecting rods, and after lubricating the crosshead pins finally escapes to the guides and drops down into the crank case, which is of oil-tight construction. When the gravity tank is dispensed with the lubricating pumps deliver direct to the bearings, and draw, as before, from the crank case. (See plate facing p. 78.)
355	Describe fuel oil filters, also state why they are required.	Filters are employed to extract impurities present in the fuel or lubricating oil. These are usually fitted in pairs, so that one can be used as a standby when cleaning or overhauling the other. The outer chamber is usually of cast iron, and contains a steel strainer of fine mesh, inlet, outlet, and by-pass valves being fitted. The cover and holding-down bolts are designed to permit of rapid and easy overhaul. See p. 88.

ELECTRICAL GENERATORS

No.	Question.	Answer.
356	Describe the construction and action of the armature and commutator of a compound wound dynamo.	**Armature.** The armature body consists of a number of soft iron discs clamped on endways to the driving boss of the dynamo, the discs being insulated from each other by means of varnish applied on either side. Slots are cut lengthways on the surface of the armature, and the insulated conductors are laid in the slots and secured firmly in position by means of binding wires. Suitable ventilation spaces are also arranged to prevent overheating when running at full load. The ends of the conductors are secured to the bars of the commutator by means of an extension piece called a "connector." As the armature revolves in the field space and cuts through the lines of magnetic force, which pass across between the magnet poles, currents are induced to flow in the armature conductors, these currents moving at right angles to the force lines. The currents thus induced are alternating in direction, the number of alternations per cycle depending directly on the number of poles. Under running conditions the armature constitutes a large and powerful magnet. *Note.* —The soft iron discs of the armature body allow of the flow of magnetic lines of force between the poles, and at the same time the varnish insulation prevents the passage of currents through the armature body in an endways direction (called "eddy" currents). See pp. 947, 980. **Commutator.** This consists of a number of copper bars, segmental in section and arranged in circular formation. The copper bars are dovetailed into position, insulated by mica, and held in place by means of an end clamping ring.

No.	QUESTION.	ANSWER.
356	— *Continued.*	Each bar is connected to the starting end of one conductor and the finishing end of another conductor of the armature, and in this way the current is "commuted" or converted from alternating current into direct current as it flows to and from the brushes. Commutators are only fitted to direct current machines, alternating machines being arranged with "slip rings," which supply the current in alternations. See pp. 948-980.
357	Referring to a dynamo, what is a short circuit? What effect would a short circuit have on the current?	A short circuit means that the electric current has taken a shorter path back to the dynamo, either by means of the positive and negative wires touching, with the insulation destroyed, or by means of some metallic contact acting as conductor between the wires. In either case the lamps on the circuit beyond the defect would be deprived of any current and would therefore go out, and the sudden rush of current back to the dynamo would cause racing, and probably serious damage to the armature.
358	Heating of dynamo: explain how prevented; also mention effect of heat on internal and external conductors.	Heating of a dynamo is prevented by having the dynamo placed in a cool position in the engine-room; also by having air spaces formed in the armature for the circulation of air. In some cases a small fan is also fitted to cool the parts. The effect of heat on the wires is to increase the resistance of the copper. Overheating of external conductors is prevented by having suitable fuses fitted. When the temperature rises to a certain point the fuse will blow out, and thus prevent damage to the lamps.
359	Define volt, ampere, ohm, watt, and 1 E.H.P.	See pp. 935-937.

No.	QUESTION.	ANSWER
360	How are cables from dynamos connected to the switchboard? Also how are circuits arranged?	**Switchboard.**—After the current is generated in the dynamo it passes from the positive brushes and leads or cables to the switchboard busbar, and from there is led away by smaller branch wires to the distribution boxes and the various lamp circuits in connection. The switchboard contains the switches or "circuit-breakers," fuses or cut-outs, volt meter and ampere meter. After the current has travelled from the switchboard through the lamp circuits; it returns to the switchboard busbar by the "negative" cables or wires, and returns again to the dynamo by the negative brushes.
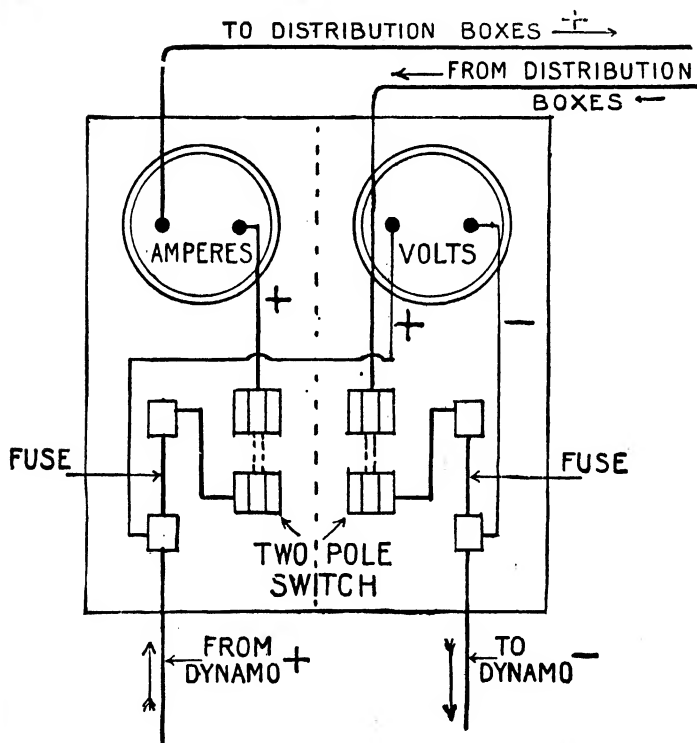
No. 448.—Diagram of Switchboard.

CONTACT PLUG

BULKHEAD

NEGATIVE

PORTABLE LAMP

POSITIVE

BULKHEAD

NEGATIVE

SWITCHBOARD

POSITIVE
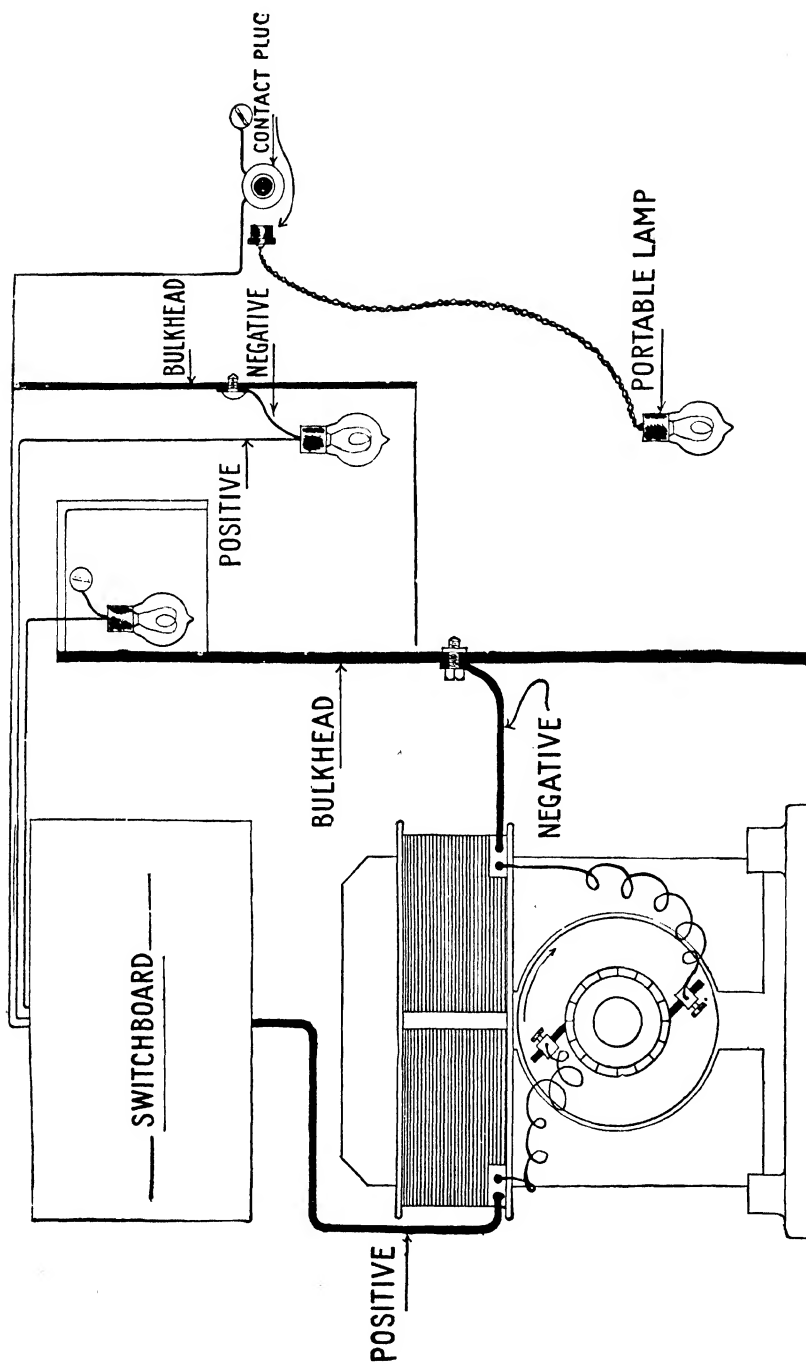
No. 449.—Single-Wire System.

No.	QUESTION.	ANSWER.
361	Describe or sketch out the single wire and double-wire systems of electric lighting.	**Single-Wire System.**

Single-Wire System.

In this system of wiring the positive current is carried by a single cable or wire to the lamps, and the return from the lamps is effected by means of the metal of the ship, or, as it is called by electricians, the return is "earthed."

The sketch shows clearly how the lamp connections are made, the return wire being metallically connected to a stud screwed into some part of the metal of the steamer. Observe that the dynamo negative cable is secured by a large stud to the bulkhead plate, the positive wire only going to the switchboard.

The advantages claimed for this arrangement are—

    1. Lower cost of installation.
    2. Less complication of wiring.
    3. Less trouble in locating faults in the circuit.

The disadvantages are—

    1. Greater danger of short circuits between lead and return.
    2. System only possesses half the insulation of the twin wire installation.
    3. Supposed cause of corrosion in condensers or other places due to galvanic action.
    4. More danger of lights going out suddenly in case of vessel grounding or in collision.
    5. Troubles experienced by rusting going on at the ship return lamp connections, owing to damp due to "sweating" of the plates, etc.

Double-Wire System.

It may be stated that the majority of new installations are of the twin wire system, this being now considered the most reliable method.
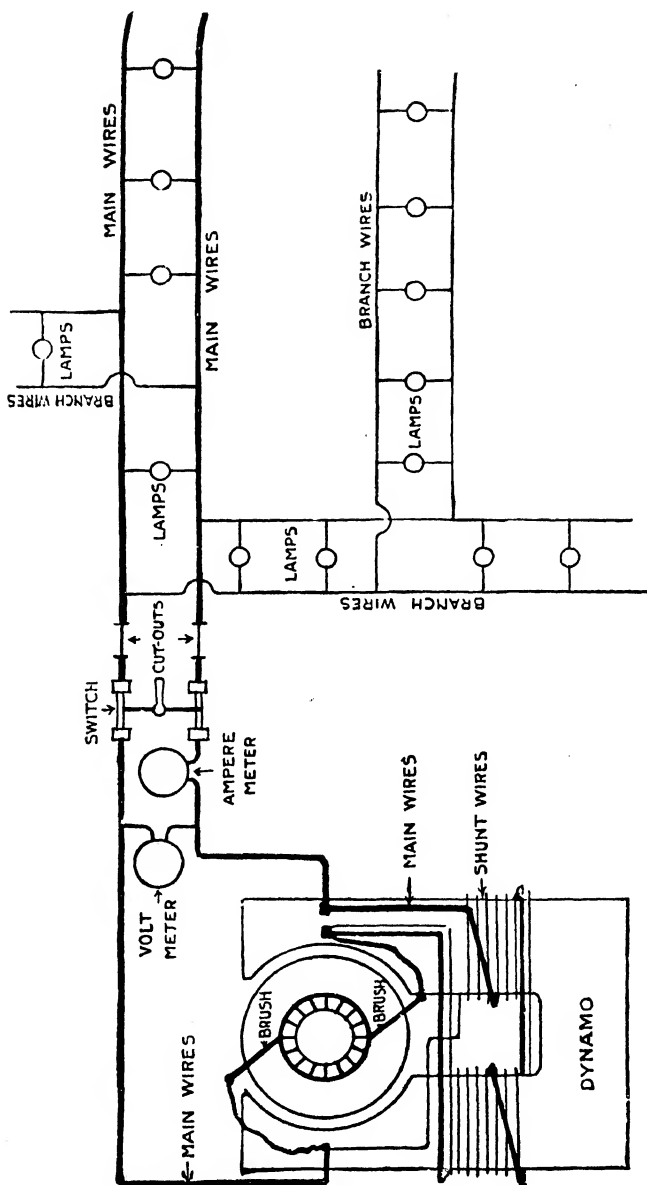
No. 450.—Double Wire System of Electric Lighting.

Three-Wire System.—In some steamers two dynamos are run *together on what is called the three-wire system.* In this arrangement the positive wires of one dynamo are connected to the negative wires of the other dynamo, and the central or neutral wire acts as a common conductor for both.

The voltage is usually 220, but as this is divided between the two, the working voltage for the circuits is only 110 volts.

The lamps are arranged so that the number of them is equally divided between the two outside wires and the central one, to balance each other and divide the current. If the same number of lamps are run on each side, the middle wire will carry no current, but should more lamps be switched in on one side than on the other, the difference of current resulting will then be carried by the central wire.

It should be noted that as the central wire has only to carry the excess or difference between the two outside wires, it can be made of less section, and is therefore of smaller size than the others.
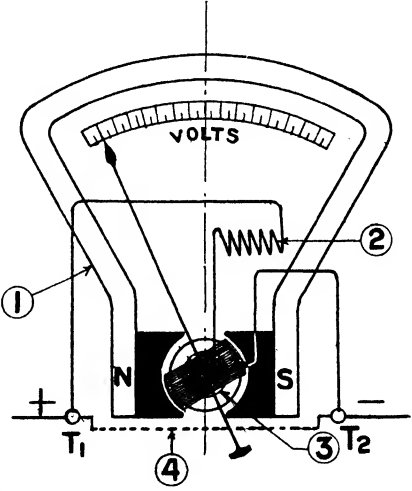
In the three-wire system the main switches and cut-outs are necessarily of the " three-pole " type.

Note.—Sea water acts very injuriously on the insulation of wires and cables unless they are protected by metal piping or are "armoured."

No.	QUESTION.	ANSWER.
362	What instruments are used for calculating the H.P. of electric generators? Also show how to work out the H.P. of the driving engine.	The E.H.P. of an electrical generator or motor can be determined as follows :— $$\text{E.H.P.} = \frac{\text{Volts} \times \text{amperes}}{746}$$ The value of one electrical horse-power is equal to 746 watts. It is only necessary, then, to take the readings of the volt meter and amp. meter and proceed as shown. The H.P. of the driving engine can be found if the mechanical efficiency is known or assumed by dividing the E.H.P. by the latter. EXAMPLE :— Volts = 110. Amps. = 850. Combined Efficiency, say, 80 per cent., or ·80. Then, $\text{E.H.P.} = \frac{110 \times 850}{746} = 125$, and $\text{I.H.P.} = 125 \div ·80 = 156.$

No.	QUESTION.	ANSWER.
363	Mention the faults likely to develop in electrical generators. What supervision is necessary?	Among others, the following faults are most likely to develop :— *A.* Sparking at brushes, which may be caused by (1) flat on commutator ; (2) short circuit between the copper blocks ; (3) faulty adjustment of brushes ; (4) mica insulation projecting beyond the copper bars. *B.* Fusing of armature conductor, due to broken coil or short circuit. *C.* Heating up of field coil, due to overload on machine. The working parts should be kept clean and free from oil, filings, or dirt. The commutator should be maintained free of flats due to wear. The governor should be accurately adjusted, so that the revolution speed remains constant all loads within, say, perhaps 3 per cent. See p. 938.
364	Describe how current is generated in a dynamo.	Current is generated in a dynamo by the inductive effect of the armature as it revolves in the field space between the magnet poles. The armature conductors cut through the lines of magnetic force and induce flow of current within themselves. To obtain electrical current magnetism is necessary, and this is supplied by the poles of the machine, which are partly magnetised to begin with.
365	Explain clearly the difference between an electrical generator and an electric motor.	An electrical generator gives out electrical current by means of mechanical power applied through the medium of a driving engine. An electrical motor is supplied with current from a generator, and gives out in return mechanical power. The construction of both generator and motor is similar, but for starting and stopping purposes a starting resistance switch is fitted to electrical motors.

No.	Question.	Answer.
366	Describe the construction and action of the instruments fitted on the switchboard to measure the current generated by a dynamo.	The volt meter registers the E.M.F. or voltage of the current, and the ampere meter registers the quantity consumed. Both meters are usually of the construction known as "moving coil" instruments, shown diagrammatically in the sketch. When the current enters the small central coil it becomes magnetised, and at once tends to overcome the tension of the small hair spring (3) and deflects the pointer to the right hand. The resistance (2) is fitted in the case of volt meters, but omitted in the case of amp. meters, which have in place of this a strong shunt wire (4) from terminal T_1 to terminal T_2. This forms the chief difference in the construction of the two instruments. Movement of the coil is due to the alternate attraction and repulsion of the permanent magnet poles whenever the coil becomes magnetised by the current.

No. 451.

1, Permanent magnet.
2, Resistance coil.
3, Hair spring.
4, Shunt wire fitted in amp. meters.
T_1, Positive terminal.
T_2, Negative terminal.
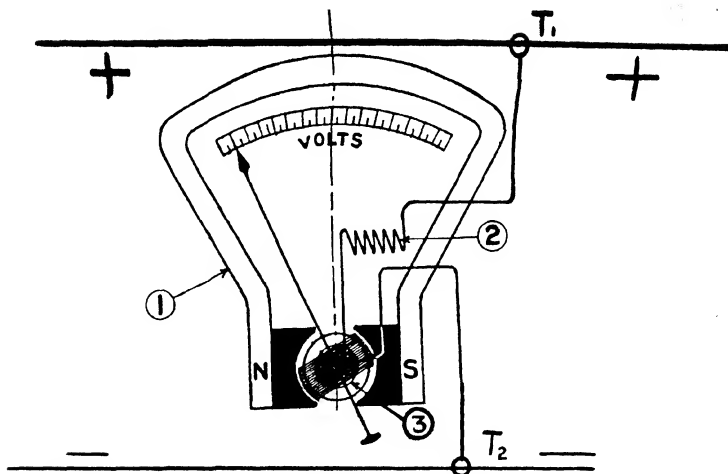
Voltmeter.

1, Permanent magnet.   3, Hair spring.
2, Resistance coil.   T₁, Positive terminal.
T₂, Negative terminal.
Voltmeter connects between positive and negative.
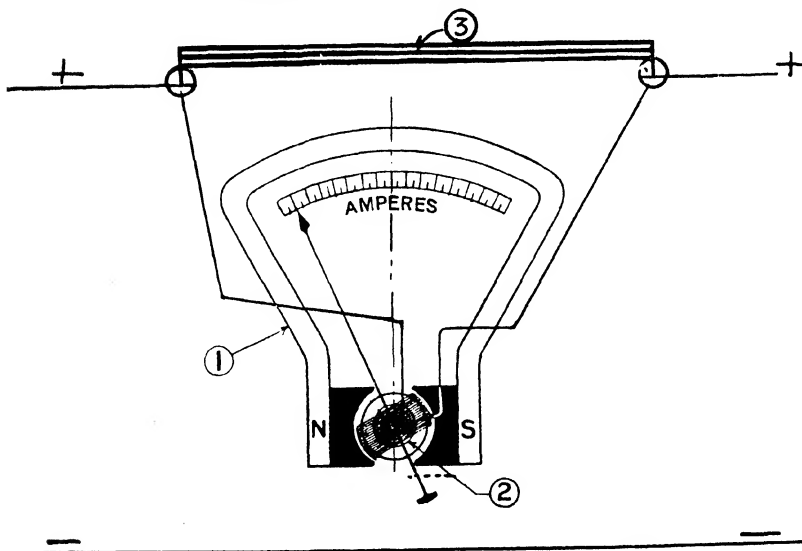
Ampere Meter.
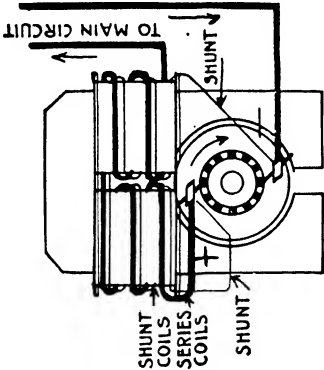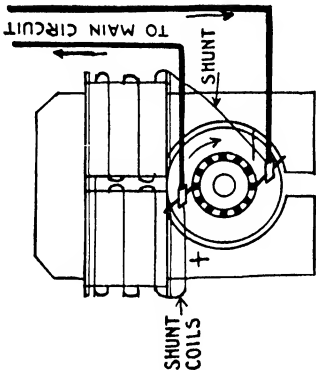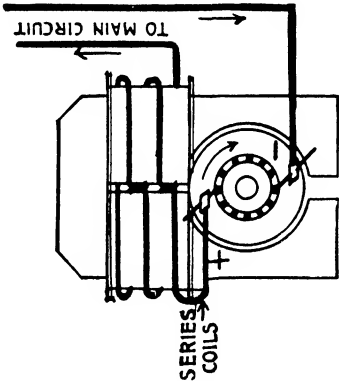
1, Permanent magnet.   2, Hair spring.
3, Shunt plates fitted in Ampmeters.
Ampmeter connects to one lead only, positive or negative.

No. 452.

NOTE.—Both Voltmeter and Ampmeter are fitted with a fixed iron core at centre.

In the Ampmeter about 95 per cent. of the current may pass through the shunt and the remaining 5 per cent. through the instrument.

No.	QUESTION.	ANSWER.
367	Describe series, shunt, and compound winding as employed for D.C. generators and motors.	

No. 453.—1. Series Winding.   2. Shunt Winding.   3. Compound Winding.

NOTE.—*Series Winding* is employed for light fan motors, where variation in speed may be required. The starting switch also functions as a speed regulator in this case.

Shunt Winding is employed for power motors, such as pumps, electro-hydraulic steering gear, etc. In addition to a special starting switch, a shunt field regulator may also be fitted for speed control purposes, and in some cases a reverser switch.

Compound winding is always employed for D.C. generator lighting sets, a shunt field regulator being provided to "raise volts," or to "lower volts," as may be found necessary when two or more machines are coupled up in parallel and are being brought into circuit.

No.	QUESTION.	ANSWER.
367	— *Continued.*	1. In *series* winding the *whole* of the current generated in the armature passes from the brushes round the field magnets, and then to the lamps and back again. 2. In *shunt* winding only part of the current passes round the field magnets, as the shunt wire to the magnets is smaller and finer than the series wire, and in this way offers more resistance to the current. 3. In *compound* winding the field magnets are wound with two sets of wire, and the whole of the current generated in the armature passes round them, but by two distinct and separate paths; first by the thick or series coils, and next by the thin or finer "shunt" coils. The object of this method of winding may be described as follows: As lamps are switched on and more current is required, the extra current, on its way to and from the lamps, passes through the series coils of the magnets, and therefore strengthens the magnetic field in proportion. Again, if a certain number of lamps are switched off, less current passes through the series coils, as less is now passing through the main wires, and this tends to maintain the correct strength in the magnetic field to keep the voltage constant at any load. It will thus be seen that a compound wound dynamo is to a great extent self-regulating, and retains practically the same voltage, no matter how many lamps are on or off. This is of great importance in ship lighting, and for this reason nearly all dynamos used for marine purposes are of the compound wound type. It should be noted that the exciting current for the magnets comes from the armature itself, and though small at first, increases as more current is developed, so that the one in a sense supplies the other in proportion to the demand.

No.	QUESTION.	ANSWER.
368	Find the H.P. driving a motor from the instruments fitted on the switchboard, also describe how the driving engine power can be determined and the fuel consumption.	Electrical H.P. $= \dfrac{\text{Volts} \times \text{Amperes}}{746}$. *Note*: 746 Watts = 1 E.H.P. Allow a **Mechanical Efficiency** of, say, **82 per cent.** Then I.H.P. = Electrical H.P. ÷·82. Allow ·4 lb. fuel per I.H.P. hour. Fuel consumption = $\dfrac{\text{I.H.P.} \times \cdot 4 \times 24}{2240} =$ Tons.
369	Why should a governor be fitted on a dynamo? What would happen if governor becomes inoperative?	Compound wound electrical generators are self-regulating if the revolution speed is kept constant. A governor is therefore essential, and if it became inoperative the lamp filaments would tend to either burn low or burn out, according to difference in armature speed.
370	Describe briefly an electrical induction coil.	Consists of a core of soft iron surrounded by two windings :— 　1. The primary circuit, or low tension wire, which receives the low tension current. 　2. The secondary winding, which consists of a greater number of coils of smaller section, and therefore higher resistance. Is used to obtain a fat spark for a motor, which operates on the battery system of ignition.
371	Sketch out and describe the construction of a compound wound dynamo.	
372	Why does a dynamo in good condition tend to heat when running? What effect has this on the load?	The resistance of the wires to the flow of electric current tends to cause a rise of temperature; also, the friction of the bearings when running at high speed. The load on the dynamo will increase with the temperature as heat energy is being generated at the expense of electrical energy.

No.	QUESTION.	ANSWER.
373	Describe briefly the Diesel electric drive, and mention the advantages claimed by this system of propulsion. What kind of dynamos are employed?	In this system of propulsion one or more Diesel engine sets are coupled direct to powerful electrical generators, which supply current to a reversible double armature motor coupled direct to the propeller shaft.
		As the tunnel shafting is done away with, considerable space is therefore saved for cargo purposes, and, among other advantages, great flexibility of power is claimed; stopping and starting losses are also eliminated, also no reversing gear need be fitted to engines as they always run in one direction. As the engines are divided up into four separate units of equal power, one, two, three, or four engines can be run as required by the power conditions obtaining. It will therefore be evident that the fuel consumption per B.H.P. will be no more when running at low powers than at full powers. Direct current is usually employed, the voltage being 220; the Diesel engine and generator revolution speed being 250, and the propeller shaft speed 90 revs. per min.
374	Metal for fuses, and why; also objections to the use of copper or iron for fuses.	Fuses are usually made of an alloy of lead and tin, or of copper and tin, which melt at low temperatures.
		Iron would not be suitable, as the temperature would then require to be much higher to produce melting of the fuse wire.
375	Describe the various electrically-driven gears on board ship.	Auxiliary compressors, water-cooling pumps, lubrication pumps, steering gear, deck winches, refrigerator, are in some cases all driven by electric motor supplied by the generators which are driven by the auxiliary Diesel engines.

No.	QUESTION.	ANSWER.
376	Describe method of control for an electric steering gear.	See pp. 526, 971-973.
377	Referring to deck winches, state which of these are most economical, and why: electric, hydraulic, and steam.	**Comparison of Steam, Hydraulic, and Electric Winches.**

Comparison of Steam, Hydraulic, and Electric Winches.

Steam.

Advantages.—

1. Direct application of power without any transmission losses.
2. Reliable and able to withstand rough usage, also easily repaired.

Disadvantages.—

1. Noisy.
2. Heavy heat losses incurred through radiation and condensation in deck steam pipe lines.

Hydraulic.

Advantages.—

1. Quiet in running, and most suitable on this account for passenger vessels.
2. Easily handled in working.

Disadvantages.—

1. Heavy installation of machinery required.
2. Transmission losses high, therefore not economical.

Electric.

Advantages.—

1. Smooth in running, and easy of manipulation.
2. Economical, as no constant heat losses occur as with steam gear.

Disadvantages.—

1. Not easy to repair if breakdown occurs.
2. Not always easily controlled as regards speed, under certain conditions of load and no load.

No.	QUESTION.	ANSWER.
378	Describe Brown's type of steering gear, and explain why, when a sea strikes the rudder, it afterwards returns to mid-position automatically. Also describe the telemotor system.	This consists of a steam tiller connected to the rudder stock, on which is mounted a steam engine driving a worm and pinion wheel, which gears with a rack quadrant fixed to the deck. The movement of the pinion and worm causes the tiller to travel round the quadrant, and so moves the rudder in the direction required. The gear wheel is driven from the engine worm through a friction clutch, and when a sea strikes the rudder, the shock sets free the clutch from the gear wheel, and so prevents any damage to the engine or gear. The telemotor system consists of a transmitting cylinder at the steering wheel, and a similar receiving cylinder at the engine aft, the two being connected by means of fluid piping. Any motion in the transmitter is repeated in the receiver, with the result that the piston of the receiving cylinder operates a pair of links against heavy spring compression, to open the control valve of the steering engine (see pp. 516, 525).

BOILERS, EVAPORATION, AND GENERAL QUESTIONS

No.	QUESTION.	ANSWER.
379	Name the likely causes of outbreaks of fire in motor ships or vessels carrying inflammable cargoes. State precautions to be taken and methods employed of fighting the fires.	Fires may be caused by (1) the ignition of oil vapour by means of a naked light; (2) leakage of oil at pipe joints; (3) oil in tanks rising in temperature to the "fire point" through overheating. In the case of inflammable cargoes, such as coal, straw, or grass, etc., gradual heating sets up chemical action which

No.	QUESTION.	ANSWER.
379	*—Continued.*	later may develop into rapid oxidation, or, as it is commonly called, combustion.

For combustion of all kinds three things are required, namely: a combustible material, a supply of oxygen, and heat.

The precautions required include the following :—

1. Absence of naked lights.
2. Ample ventilation.
3. Avoidance of leakage at oil pipe joints or oil tanks.
4. The fitting of screw-down valves to fuel supply connections, with extension rods to deck.

For the extinguishing of fires the following methods may be adopted according to circumstances :—

1. Shutting off the air supply (in most cases impracticable).
2. Steam jet directed on the fire.
3. Flooding the tank tops with water, which has the effect of lowering the oil temperature to below the fire point.
4. The use of CO_2 gas, discharged from steel bottles.
5. The use of "Petrofoam" or "Phomene," which consist of a spongy mass of CO_2 in the condition of a semi-solid. The CO_2 in this form blankets off the air, and the fire then dies out through want of atmospheric oxygen.

The substances named usually consist of an acid (sulphuric) and an alkali (bicarbonate of soda) in a container, and these are allowed to mix under water pressure or compressed air when the appliance is in use, the chemical combination resulting in the production of CO_2 in the condition described, which is then discharged from a hose-pipe nozzle on to the fire. (Also see p. 377.)

No.	QUESTION.	ANSWER.
380	State the precautions taken against fire on board ships with (*a*) internal combustion engines, and (*b*) oil fired boilers.	The precautions taken against fire in either oil burning vessels or in internal combustion engined vessels are similar, and consist of : — *A.* Boxes of sand for dealing with small outbreaks. *B.* Bottles of CO_2 gas under pressure. *C.* Supplies of " Petrofoam " which consists of an acid and an alkali which are brought together under a pressure of water supplied by a pump. When these combine a thick foam or froth is produced, which acts effectively to smother out a fire. The froth obtained in the manner described consists of CO_2 in a partly solid state and which is, of course, a non-supporter of combustion. *Note.* In oil burning vessels steam spraying pipes are often fitted for the double bottom oil tanks to cope with fires, in addition to the foregoing appliance described. See pp. 377, 767.
381	Name the gases found in oil tanks after pumping out. How are these gases got rid of? What danger may the presence of the gases lead to?	After pumping out tanks which have contained oil, the gases found consist chiefly of CH_4 (marsh gas). This gas is highly explosive when mixed with 10 parts of air in the presence of a naked light. The gases can be got rid of by the following methods :— *A.* Filling up the tank with water. *B.* Inserting a steam hose into the tank and "steaming out." *C.* By means of exhausting or ventilating fans, which draw out the gas. Also see p. 892. *Note.*—To test for the presence of explosive gases, a Davy safety lamp should be employed, and in the use of which caution should be observed (see p. 857).

No.	QUESTION.	ANSWER.
382	What precautions should be taken to prevent fire due to leakage in a pipe line ?	By the fitting of copper wire gauze diaphragms at the open ends of swan-neck pipes. If fire takes place on one side, it cannot easily pass through to the other side of the copper diaphragm. *Note.*—Petrol vapour is heavier than air, and when forming falls to a lower level. The most violent explosion occurs when petrol vapour is mixed with air in the ratio of 19 of air to 1 of petrol vapour.
383	Referring to gases in oil tanks, state what proportions of atmospheric air and fire damp will give the most violent explosive result. What is the effect of (*a*) decreasing the proportion of air, and (*b*) of increasing the proportion of air ? Mention how a serious fire may be extinguished by means of fire-fighting appliances and substances.	The most violent explosion occurs when the proportion of air to gas by volume is as 9·5 is to 1. If the air supply is less than this the explosion will be less violent, and the same holds good when the air supply is in excess of the proportion stated. If the air supply is unlimited (such as in the open air), the gas may only ignite and burn in place of exploding. The danger of explosion is therefore greatest in confined spaces, such as tanks, when the air supply is limited in quantity. It should be noted that before combustion of any kind can be brought about, the presence of atmospheric oxygen is necessary. When a serious fire breaks out in, say, the double-bottom oil tanks, the application of a fire-fighting substance, such as " Petrofoam," for example, results in the deposit of CO_2 in the condition of a spongy solid ; and this, being a non-supporter of combustion, prevents the admission of oxygen, which, as already explained, strongly induces combustion to take place. If the admission of atmospheric air to the tank could be absolutely shut off, the fire would in due time die out through want of oxygen. See pp. 377, 767.

No.	QUESTION.	ANSWER.
384	Describe a water-tube boiler, and name the materials of which it is constructed.	The Babcock & Wilcox boiler consists of an arrangement of inclined tubes forming the bulk of the heating surface, sinuous boxes or headers to which the tubes are attached, a horizontal steam and water drum, a mud drum, and a furnace of large capacity immediately beneath the inclined tubes, the relative positions of which are shown on pp. 547, 552, 658.

The inclined tubes are divided into vertical sections and, to ensure the continuous circulation of water in one direction, they are placed at an inclination of 15° from the horizontal. The tubes are so arranged in order to break up and ensure efficient contact with the products of combustion.

By distributing the heating surface into sectional elements, all danger from unequal expansion due to raising steam quickly, or sudden cooling, is at once precluded. Each section is made up of a series of straight tubes, expanded at their ends into sinuous steel boxes known as "headers." The tubes are thus staggered.

Extending across the front of the boiler and connected to the upper ends of the front headers by short tubes is a horizontal steam and water drum of ample dimensions. As the upper ends of the rear headers are also connected to this drum by horizontal tubes, each section is provided with an inlet and outlet for steam and water.

Across the bottom of the front headers, and connected thereto by short tubes or nipples, is a forged steel box of square section. This box being situated at the lower corner of the bank of tubes, forms a blow-off connection or sediment box through which the boiler can be completely drained. |

No.	QUESTION.	ANSWER.
384	*—Continued.*	The circulation of water is as follows : Heat being applied to the inclined tubes and steam formed, the mixture of water and steam rises to the high end . and flows through the uptake headers and horizontal return tubes to the steam and water drum, the path of both water and steam being short and direct ; the water evaporated in the tubes being replaced by water flowing directly from the bottom of the drum downwards through the front headers and into the tubes, part of this water to be in turn evaporated. The tubes are of seamless steel.
385	Describe how the water tubes of a Yarrow boiler are secured in position.	After insertion in the holes of the upper and lower drums, the tubes are expanded in place by an automatic tube expander, and are finally thinned out to a bell mouth shape at either end. This method of securing the tubes effectually prevents them from drawing out of the tube holes, and in addition promotes circulation. See pp. 544, 658.
386	Mention the faults common to water-tube boilers, and describe how these are remedied.	1. Leaky tubes or tube header doors. 2. Scale deposit in tubes. 3. Distortion of tubes nearest the flame. 4. Corrosion in steam drums. Leaky tubes can be plugged up, or can be cut out and replaced. Scale deposit can be avoided by the use of absolutely pure (distilled) feed water. Corrosion in the steam drums is usually caused by the generation of gases (Hydrochloric acid gas) formed from acids in sea water feed, and, as in the case of scale, can be prevented by using only the purest of fresh water as feed. Distortion of the tubes can be prevented by putting an original "set" or bend on the tubes to counteract the effects of heat expansion, and having tubes of larger diameter in the lower two rows next to the fire.

No.	Question.	Answer.
387	State the causes of leaky tubes in the case of water - tube boilers and cylindrical boilers, also the remedies applied to arrest leakage.	Leaky tubes in water-tube boilers are caused, in most cases, by heat distortion, the lower rows being most often affected. In cylindrical boilers the cause of leaky tubes is either unequal expansion or contraction between plate and tube, or by the tubes becoming loose in the tube plate holes. Leakage ultimately sets up corrosion. Leakage is arrested in water-tube boilers by re-expanding, or by driving in tapered plugs into the ends of the tubes. In the case of bad leakage the tube should be cut out and replaced. In cylindrical boilers the method adopted is to drive the tubes further through the tube plates and re-expand. For a split tube a patent stopper is usually fitted to close up the defective tube until replacement can be carried out.
388	Describe briefly a Babcock water-tube boiler. How is circulation of water provided for?	
389	Mention three ways in which a single riveted lap joint may give out.	1. By shearing of the rivets. 2. By cracking of the plate between the rivet holes. 3. By crushing out of the plate metal between edge of rivet hole and edge of plate.
390	Mention where boiler tubes leak, and give the causes, also the remedies or preventions.	Boiler tubes tend to leak at the back ends which are exposed to the high temperature of the combustion chamber gases, and which set up unequal expansion of tube plate and tube. The plates and tubes require to be kept as clear of scale deposit as possible, as deposit increases the overheating effect. The tubes, if leaky, can be re-expanded.

D.B.
Straps

D B
Straps
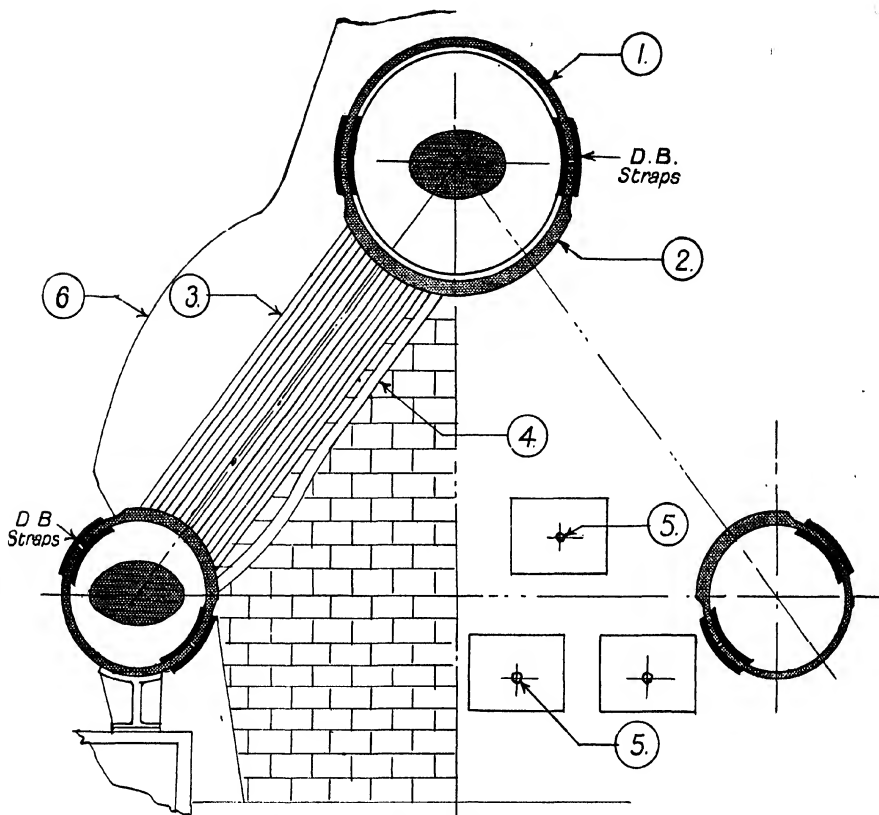
No. 454.—Yarrow W.T. Boiler.

(Sketch suitable for Examination Purposes.)

1, Steam drum, $\frac{5}{8}$ in. thick.
2, Plate rolled to $1\frac{5}{8}$ in. thick to allow of tube expanding.
3, Tubes, $1\frac{1}{8}$ in. diameter.
4, Tubes, with set, $1\frac{1}{2}$ in. diameter.
5, Oil fuel burners.
6, Air casing, asbestos lined.

The tubes and drums are constructed of mild steel. No screwed joints are employed, the tubes being expanded and belled out at the ends. The pressure carried ranges from 250 to 550 lbs. per sq. in. In naval practice one boiler may be sufficient for an output of as much as 10000 S.H.P.

The feed water enters the steam drum through the check valve after passing through the automatic feed regulator valve, and circulates down the outer tube rows and up the inner tube rows nearest to the flame.
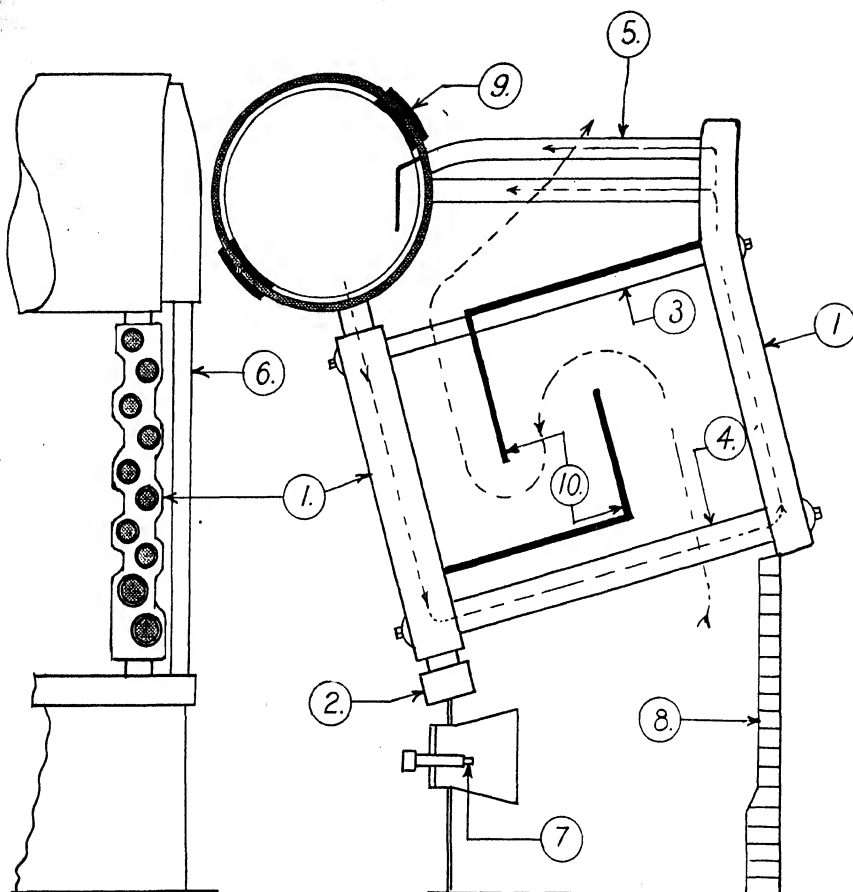
No. 455.—Babcock W.T. Boiler.
(Sketch suitable for Examination Purposes.)

1, Steel headers into which the tubes are expanded.
2, Mud drum to which is attached the bottom blow-off cock.
3, Upper tubes of about $2\frac{1}{2}$ in. diameter.
4, Lower tubes (two rows) of about 4 in. diameter.
5, Dry tubes.
6, Downcomer for cold feed to flow into mud drum.
7, Oil fuel burner.
8, Fire brick.
9, Double butt strap joint.
10, Baffles for flow of gases.

Tubes and drums of mild steel, and headers of forged steel. The arrows show, respectively, the circulation of the water and the flow of the gases of combustion.

No.	QUESTION.	ANSWER.
391	Name all boiler mountings, and where connected to. What precautionary measures are required in operating the same? What attentions are required?	1. Main stop valve, connecting boiler with main engines. 2. Auxiliary stop valve, connecting main boiler with auxiliary engines, such as pumps, dynamo engines, etc. 3. Main feed check, connecting main feed pumps and boiler. 4. Donkey feed check valve, connecting donkey pump with main boilers. 5. Blow-down valve, connecting bottom of boiler with valve on ship's side. 6. Scum cock, connecting surface of boiler with ship's side or bilges. 7. Salinometer cock, for testing boiler density. 8. Safety valve, with connection to waste steam pipe. 9. Whistle valve, with steam to whistle. 10. Pressure gauge. 11. Test cocks on column. 12. Water gauge cocks to ascertain water level. Before opening the stop valve, drains or steam pipe should be opened and then closed. Blow-down on ship's side should be opened first and boiler blow-down should be closed first. Safety valves should be examined for wear, corrosion, broken springs, etc. Check valves should be examined for slack seats, gland packing, etc.
392	Name the effective heating surfaces of a boiler, also the parts where scale is likely to deposit. If the scale deposit is excessive, what danger may this lead to?	The effective heating surfaces of a boiler consist of the following :— A. Upper half surfaces of the furnaces (if coal fired). B. Sides, back, and top of the combustion chambers, from above the line of fire bars only. C. External surface of the tubes. Scale deposit occurs on the furnace crowns, tubes, tube plates, and combustion chamber tops. Excessive scale deposit may lead to overheating and collapse of the parts affected.

No.	QUESTION.	ANSWER.
393	State the average efficiency of boilers, engines, shafting, and propellers; also give the overall efficiency both for steam practice and Diesel practice.	**Steam Practice.** Boiler efficiency $= 75$ per cent. Indicated thermal efficiency $= 15$,, Mechanical efficiency $= 85$,, Propeller efficiency $= 65$,, The overall, or combined efficiency, is obtained as follows :— Then, Overall efficiency $= \dfrac{75}{100} \times \dfrac{15}{100} \times \dfrac{85}{100} \times \dfrac{65}{100} =$ ·0621, or 6·21 per cent. **Diesel Practice.** Indicated thermal efficiency $= 42$ per cent. Mechanical efficiency $= 80$,, Propeller efficiency $= 65$,, Then, Overall efficiency $= \dfrac{42}{100} \times \dfrac{80}{100} \times \dfrac{65}{100} =$ ·218, or 21·8 per cent. It should be noted that in Diesel engine practice boiler losses are eliminated, also that the thermal efficiency is much higher. The mechanical efficiency, however, is lower, owing to the power required to drive the air compressors. From the foregoing, it will be evident that the oil fuel consumption in Diesel engines per I.H.P. per hour is roughly about one-third that of steam engines with oil-fired boilers.
394	How are boiler tubes fixed, also stay tubes? If the back ends of tubes burn away, how are they repaired?	Plain boiler tubes are expanded in position by means of a three-roller type tube expander. Stay tubes are heavier in construction, and are screwed through both tube plates and expanded or caulked, after which thin flat nuts are screwed on at the front ends of the tubes. A repair for burning of the tubes at the back ends is to drive through the tubes further into the plates and re-expand or caulk.

No.	QUESTION.	ANSWER.
395	Describe the operation of cutting and drawing out defective smoke tubes and stay tubes; also describe how the tubes are replaced.	The usual method of removing a defective tube may be described as follows: The beading at the back end of the tube is first cut off flush with the plate, and the tube end cut or ripped in three or four places. The end thus cut up is then hammered inwards, and the bar or rod passed through the tube, with a strong washer fitted in position over the tube end, the washer diameter being of course less than the diameter of the hole. At the front end a dog is fitted and a screwing up nut; if the bar is then held by the square on the end, and the nut tightened up, the tube will, in most cases, be started and finally drawn out. The plain tubes are expanded in position, and the stay tubes are screwed into place, expanded or caulked, and fitted with thin nuts at the front end.
396	Describe how to repair a leaky boiler tube. Describe a tube stopper.	A leaky boiler tube should be re-expanded with a tube expander, which consists of a tapered mandril and three rollers, which are forced out by tapping the mandril in with a hammer while the mandril is being revolved. A patent tube stopper consists of a tube, or distance piece, with a long rod which fits into the boiler tube, with a nut at the front end for screwing up. An asbestos washer is placed between two iron washers at either end with the distance piece in between, and when a nut at the front end is screwed up, the asbestos is pressed out against the tube and so forms a steam-tight joint.
397	Describe a safety valve for a boiler. Explain how it is adjusted, and how overloading of the valve is prevented.	A safety valve consists of a cast-iron chest, within which is contained a brass valve, seat, and spindle. The valve is loaded by means of a steel spring of about $\frac{3}{4}$ in. square section, which is compressed to the required amount by means of a nut and adjustment washers of brass.

Washer

12 Coils
3/4" square steel

Drain

waste
Steam
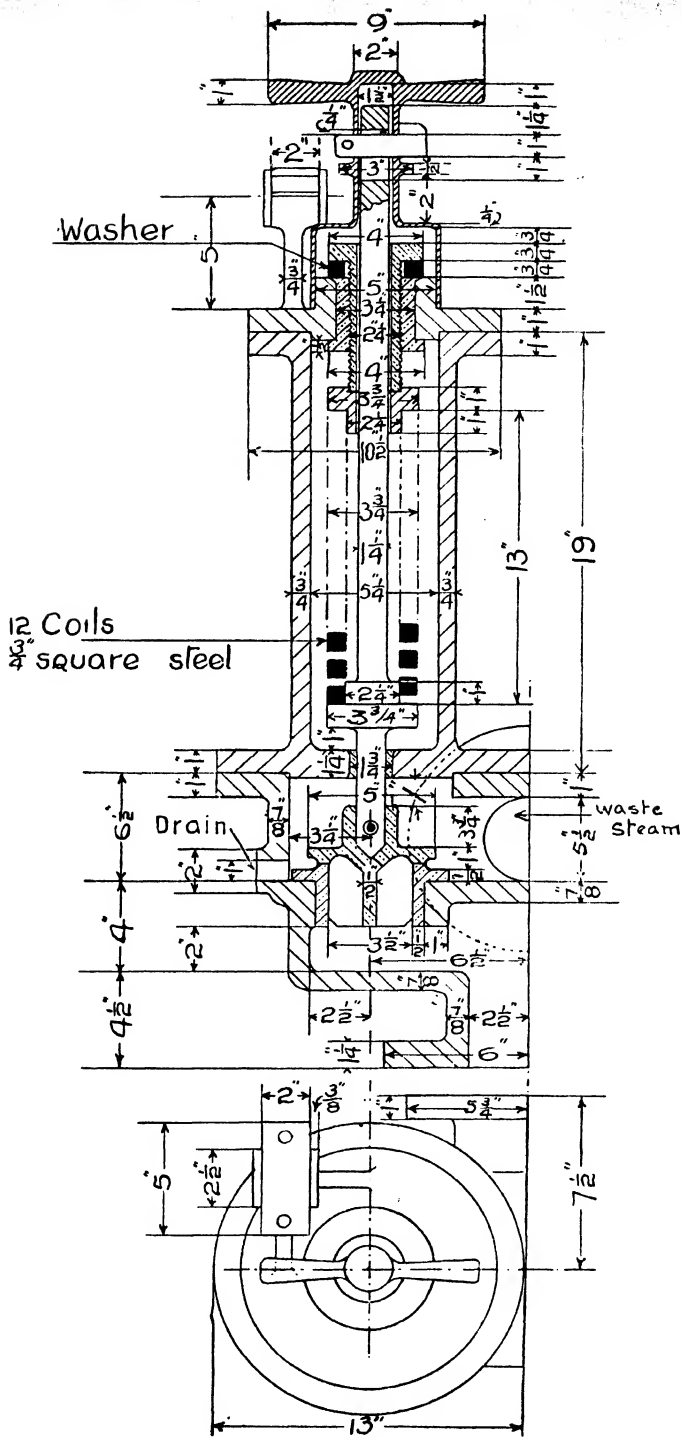
No. 457.—Pair of Spring-Loaded Safety Valves.

Data.—Working Pressure= 160 lbs. gauge.

Total heating surface (T.H.S.)=2245 square feet.

B. of T. Rule=T.H.S. × K=Combined Valve Area × Absolute Pressure.

Note.—K=1·25 for coal firing and natural draught.

K=1·5 for oil firing and forced draught.

Assuming either coal with forced draught or oil firing.

Then,
$$2245 \times 1 \cdot 5 = d^2 \times \tfrac{11}{14} \times 2 \times (160 + 14 \cdot 7).$$
$$3367 \cdot 5 = d^2 \times \tfrac{11}{14} \times 2 \times 174 \cdot 7.$$

Then,
$$d = \frac{3367 \cdot 5}{\tfrac{11}{14} \times 2 \times 174 \cdot 7} = 3 \cdot 5 \text{ in. diameter (each valve).}$$

When Cockburn patent-type high-lift valves are fitted, the area accepted by the B. of T. requires to be only half that as found by the foregoing calculation.

Rule, $11000 \times d^3$=Spring load on valve × Mean diameter of coil.

Where,   11000=Constant for square steel.

   „ d=Side of square coil in inches.

Allow, say, 50 lbs. for combined external weights of valve, spindle, and spring.   Mean diameter of coil=(say) 3 in.

Then,
$$11000 \times d^3 = ((3 \cdot 5^2 \times \tfrac{11}{14} \times 160) - 50) \times 3 \text{ in.}$$

   „
$$11000 \times d^3 = (1539 \cdot 2 - 50) \times 3 \text{ in.}$$

So that $d = \sqrt[3]{\dfrac{1489 \cdot 2 \times 3 \text{ in.}}{11000}} = \cdot 74$ in., say ¾ in. square steel.

Note.—Cube root extraction is required.

Diameter of boiler branch bore=$\sqrt{3 \cdot 5^2 \times 2}$=4·9 in., say 5 in. diameter.

Flange Studs.

Allow, say, 3000 lbs. per sq. in. stress on studs, and assume pressure to act out as far as the pitch centre line of the studs; also take pitch circle diameter as 10 in. or 10½ in. and fix on number of studs as 6.

Then,   Diameter of studs=$\sqrt{\dfrac{10 \cdot 5^2 \times 160}{3000 \times 6}}$=·9, say 1 in. diameter.
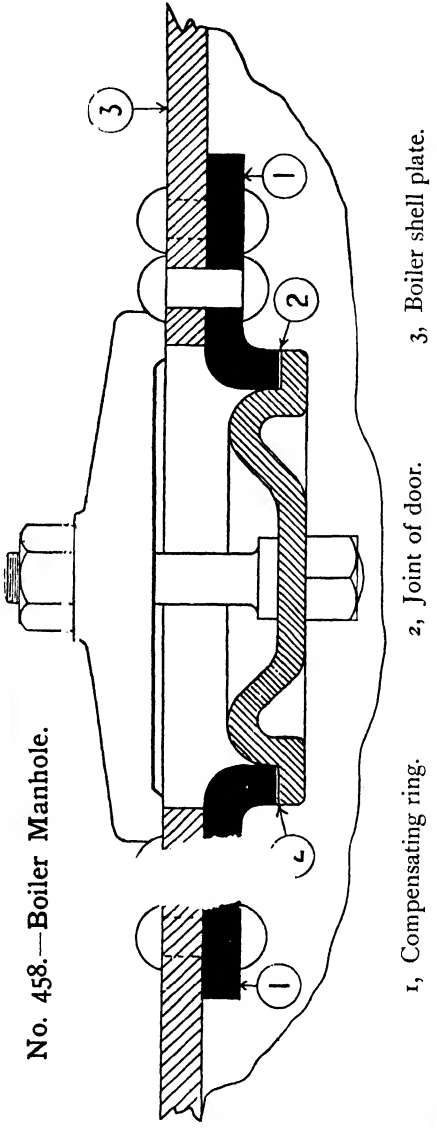
Note.—Only one valve of the pair is shown.
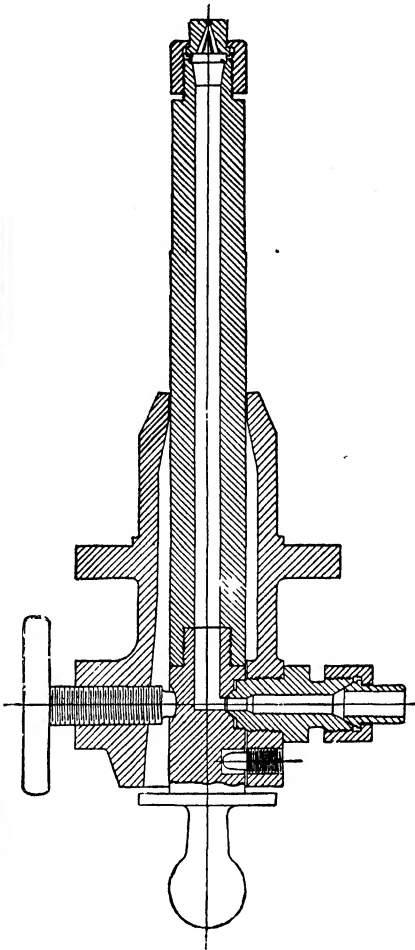
   „   The valve seat is secured in position by means of 3 screwed pins, this precaution being of importance.

Note.—Area of waste steam pipe to be equal to 1·1 times the combined valve area.

No.	QUESTION.	ANSWER.
397	—*Continued.*	The upper end of the chest is fitted with a loose covering cap, which is arranged with a collar on which the easing gear levers bear. A cotter passes through both the cap and valve spindle, clearance for lift ($\frac{1}{4}$ valve diameter) being allowed for below the cotter in the slot cut out of the valve spindle. This device effectually prevents overloading and at the same time permits of the valve being eased to blow off. See pp. 662, 663.
398	Referring to boiler shells and starting air tanks, state the nature and intensity of the stresses acting in the longitudinal and circumferential direction; also give the rules to prove this.	Boiler shells and starting air tanks are subjected to tensile stress. The stress acting longitudinally is equal to twice that in the circumferential direction, therefore special riveting (double butt strap joint) is required on the longitudinal seams. The following formulæ prove the stress ratios :— $$\frac{\text{Diameter}'' \times \text{Pressure}}{T'' \times 2} = \text{Longitudinal Stress.}$$ $$\frac{\text{Diameter}''^2 \times 1\frac{1}{2} \times \text{Pressure}}{\text{Diameter} \times 3\cdot14 \times T''} = \text{Circumferential Stress.}$$ **Where T=thickness of shell.**
399	What is a CO_2 recorder? What useful information can be obtained from same? Why is it not used more at the present time?	A **CO_2 Recorder** consists of a system of glass tubes and bulbs interconnected and attached to a pipe leading to the funnel. Water at low pressure circulating through a set of U tubes creates a vacuum, which draws in samples of the funnel gases. These samples then pass through a solution of caustic potash, which absorbs any CO_2 present. The gases remaining passing on act on a small piston, which operates a pen on the recording drum paper. The higher the per cent. of CO_2 present, the lower will the pen mark appear on the paper, as less gas is then left to raise the pen piston.

No.	QUESTION.	ANSWER.
400	Enumerate in correct order the appliances and fittings through which oil fuel passes on its way from the storage tanks to the boiler furnaces.	The oil fuel is first pumped into the ship's bunkers (which usually consist of side tanks, deep tanks, or double bottoms) by means of large diameter filling pipes fitted with sluice or gate valves, the connections being similar to those fitted for ballast tanks. Allowance is made for expansion of the oil due to rise of temperature either by expansion trunks or by overflow from one tank into another, or by only filling up the tanks to about 95 per cent. of full capacity. A transfer pump draws the cold oil from the oil bunkers or storage tanks, and discharges into the settling tanks, usually two in number, and placed at a higher level, such as the main deck ; the oil is then heated in the settling tanks by steam coils to perhaps $110°$ or $115°$ to produce separation of the water, and is next drawn off by the oil service pump through the cold filter of coarse mesh, and is discharged through one to two heaters, where the temperature is raised to slightly above that of the flash point by means of direct boiler steam. After leaving the heater the oil is forced through the hot filter of fine mesh and then passes direct to the boiler distribution header to the various burners of the furnaces. The hot oil is atomised into a fine mist on leaving the burner nozzle, and enters the furnace in the form of a hollow cone, the colour of the gases being of dazzling white if combustion is complete, which gives a corresponding colour of light grey haze to the funnel smoke.

No.	QUESTION.	ANSWER.
401	Sketch out a manhole door and compensating ring for a main boiler, and mention where the rivets and plate are most likely to give out.	

No. 458.—Boiler Manhole.

3, Boiler shell plate.

2, Joint of door.

1, Compensating ring.

As the stress longitudinally is equal to twice the stress circumferentially the rivets or plates are most likely to give out in the longitudinal direction.

No.	QUESTION.	ANSWER.
402	Describe in detail, or sketch, an oil fuel burner.	

No. 459.—Wallsend-Howden Improved Type Burner.

The oil, under pressure, is forced through the small holes of the diaphragm, and enters the furnace in a finely atomised condition.

By easing back the locking screw, shown through carrier on top, the burner can be quickly lifted up and withdrawn, and a new burner as quickly placed in position.

No.	Question.	Answer.
403	Referring to oil fuel burning, state the causes and give the remedy for the following faults: (a) Black smoke at funnel top; (b) white smoke at funnel top; (c) burners dripping; (d) boilers panting; (e) sputtering at burners; (f) burners go out.	_See sub-table below._

Effect.	Cause.	Remedy.
Black smoke -	{ Want of air } { Cold oil }	Give increased air supply, or, raise oil temperature
White smoke -	Excessive air	Reduce air supply
Burners dripping -	(a) Oil too low in temperature	Raise oil temperature or oil pressure
Boilers panting -	(b) Low oil pressure	
Sputtering at burners	Excessive temperature and want of air, or excessive oil pressure — Water or air in oil	Reduce temperature in furnace by increasing air supply — Test for air and for water leakage in heaters
Burners go out -	Air, water, or solid matter present in the oil	Ditto, also test filters for solid deposits

No.	Question.	Answer.
404	Describe how to test if tail shaft is down; how much to allow with safety; how to line up tail shaft, if necessary.	With the ship in the dry dock, a feeler should be inserted between the propeller shaft and the lignum vitæ bush at the top. The clearance measured on top side will show how much the shaft is down. No more than $\frac{3}{4}$ in. wear down should be allowed, as beyond this rebushing would be advisable. The propeller shaft can be lined up by renewing the hard wood strips of the stern bush.

No.	QUESTION.	ANSWER.
405	Describe an evaporator and its fittings. Explain the most economical method of working. State the approximate coal consumption per ton of fresh water evaporated.	An evaporator is fitted to produce fresh water suitable for boiler feed water purposes, and its operation is as follows: Low pressure or high pressure steam is blown through the copper coils of the evaporator, and the latent heat of the steam is given up to cause evaporation of the sea water which surrounds the coils. The condensed steam from the coils and the steam generated in the evaporator are both utilised as fresh feed water, as the coil drain is led to the hot well and the evaporated steam to the condenser, L.P. receiver, or feed heater, according to the steam pressure generated.

Evaporators work most economically with low pressure steam, and at a density of from 15 to 16 oz. per gallon. Evaporator capacity allowance is from 8 to 10 tons per 1000 I.H.P., so that engines of, say, 2000 I.H.P. would be fitted with 20-ton evaporator.

Evaporator coils are usually supplied with boiler steam, which passes through a reducing pressure nozzle fitted between the evaporator stop valve and the copper coils.

Economical Method of Working Evaporator.

1. Keep as far as possible a uniform density in the shell to reduce scale deposit to a minimum.
2. Drain from coils should be led to the feed tank.
3. The vapour produced should, where possible, be led to the hot well or feed tank.
4. Work at a pressure of about 5 lbs. gauge, and heating steam (reduced) of about 60 lbs. gauge.
5. Maintain a working density of from 15 to 16 oz. per gallon.

To evaporate one ton fresh water requires about 280 lbs. of coal.

No.	QUESTION.	ANSWER.
406	Sketch out and describe a Davy type safety lamp.	This type of lamp is employed for the detection of explosive gases, fire damp (marsh gas) in pumped-out oil tanks, or choke damp (CO_2 gas) in ballast tanks. The copper gauze envelope which surrounds the lamp quickly absorbs the low heat of the wick flame, which is thus dissipated before it can pass from the inside to the outside of the lamp and cause an explosion. It should, however, be noted that the lamp requires careful handling, that is, it must not be swung about freely, but should be held as steadily as possible when being used for the detection of explosive gases. If the proportion of marsh gas (fire damp) present in the atmosphere exceeds 3 per cent., a faint and tri-angular-shaped blue-coloured cap appears about the flame, the appearance of which is therefore a sign of danger. **Testing.** 1. If the flame burns clear, the atmosphere is free from foul air or dangerous gas. 2. If the flame develops a faint blue cap above, then fire damp is present and danger of explosion exists. 3. If the lamp burns black or goes out, CO_2 gas (fatal to life) is present. See p. 857.
407	Sketch out a stern tube bush and show the waterways. Describe how the bush is secured in position.	See facing p. 1054. The stern bush is pinned on to the flange of the stern tube, and the check ring is in turn pinned on to the flange of the stern bush, the ring being scalloped out to admit of the alternate fitting of the screws or pins.

No.	QUESTION.	ANSWER.
408	Describe a propeller boss, and how constructed and machined; also materials employed. How are the blades secured?	Propeller bosses are of cast iron or cast steel when the blades are separate, the latter being of phosphor bronze or similar material. The blades are secured by means of seven or eight studs, fitted with Muntz metal close-ended nuts.
		The propeller boss is first cast with the hole for the taper roughed out, and after being marked off with the necessary proof lines, it is then securely bolted down to the table of a horizontal boring machine.
		The tool-holder is formed with the necessary taper (say, $\frac{7}{8}$ or 1 in. per ft.), and the feed-screw is fixed on the holder at the same angle, so that when the tool revolves, the cutter can be fed forward a certain amount at each turn. The bar is passed through the hole in the boss and rests on bearings at either end, the drive usually being by electric motor.
		The tool is now adjusted and the machine started, and, as the cutting tool feeds in, the hole is bored out, beginning at the larger diameter and finishing at the smaller diameter. The work is tested for accuracy by means of a tapered template. Without moving the boss, one face can be machined, and if the boss or the table is then turned through an angle of 180° the other face can also be machined in turn.
		The boss is now readjusted on the table and the faces which receive the blades are accurately machined, the work being finally completed by the drilling of the holes for the flange studs, and the cutting of the featherway.
409	Describe the method of fixing engines on board ship with reference to alignment, etc.	See facing p. 1054.

No.	QUESTION.	ANSWER.
410	How is the pitch of propellers taken in the case of twin-screw vessels? What instruments are required for the purpose?	

No. 460.

1, Wooden block.

2, Strip of light sheet iron or steel ($\frac{5}{8}$ in.), with a brass ferrule passed through a hole and secured.

3, Poker gauge, say, $\frac{3}{4}$ in. diameter; an easy fit in ferrule.

To Measure Pitch.

1. Fix up the plate in the wood block so that it is exactly parallel to the machined back face of the boss, as shown by E, E.

2. Arrange that the poker is placed at a radial position of, say, $\frac{2}{3}$ out from centre of boss.

3. With propeller blade in any position, and opposite the poker gauge, push in the latter until it makes contact with the blade surface, then score a mark A at the position of the ferrule.

4. Arrange with the engine-room staff that on a signal the shaft will be turned exactly $\frac{1}{12}$ of one revolution (by means of marks on, say, the main bearings), and when this is done, either push in or draw out the gauge as required by the blade movement, and again mark the poker at B (if the gauge is drawn out).

No.	QUESTION.	ANSWER.
410	—*Continued.*	The distance between the marks A and B, measured in inches, is exactly equal to the full pitch in feet at the radial position of the poker. Thus, Distance $p = \frac{1}{12}$ of pitch. Then, $\dfrac{\text{Distance } p \text{ in inches} \times 12}{12 \text{ in.}} = \text{pitch in feet.}$ But as 12 cancels out top and bottom, distance p in inches will therefore be the full pitch in feet. This method can be applied to either single or twin screw vessels, with the propeller shafts horizontal, or, as usually found in practice, slightly inclined upwards and inboard.
411	Show by a sketch the method of securing the propeller boss to the stern shaft. Describe the method adopted to remove the boss if fixed very rigidly on the shaft.	If propeller will not start off keys by means of stud plate on end of shaft, heat up boss by means of wood fire, and keep screwing up studs on end of boss. If this fails, draw packing ring out of inner end of boss, take out packing, and put gland back into place, being careful that it is below flush of face of boss. Drive wedges in between face of boss and stern tube; keep on drawing and screwing up, heating up the boss with molten lead if necessary. If wing propeller, shaft brackets must be shored to take strain off wedging.
412	Explain the meaning of "Elastic Limit" and "Modulus of Elasticity" referring to metals.	**Elastic Limit.**—Up to a certain load a bar remains elastic in nature; that is, when the load is relieved the material will creep back to its original shape. If, however, the load exceeds the elastic limit, the material will remain distorted, as permanent set will have developed. **Modulus of Elasticity.**—By this is meant the ratio of stress to strain, or the force per square inch required to double the length of bar by tensile stress or reduce it to half by compressive stress, assuming that the bar possesses unlimited elasticity. **For mild steel, Modulus = 30000000 lbs.** ☐.

No.	QUESTION.	ANSWER.
413	Describe a type of stern tube in which the shaft is lubricated with oil and what advantages are claimed for it.	In the Cedervall patent stern tube, oil is employed as a lubricant in place of water, the propeller shaft having the brass liner omitted, the stern bush being of white metal. Gravity flow lubrication is sometimes employed, a tank containing the oil being placed overhead aft in a suitable position to supply the tube. The principal objects of this invention are to absolutely prevent the access of any external water to the stern tube, and to provide a reservoir of oil capable of supplying a steady and continuous lubrication to the whole bearing surface. The invention consists, essentially, of an annular box of brass or gun-metal, containing an inner packing ring, which is pressed outwards by a series of small spiral springs. The box fits over the shaft, and is fixed to the forward face of the propeller boss by means of screws, thus turning with the propeller, and the inner movable ring presses against the prepared face of the stern tube bush. The springs, while of ample strength, are of such elasticity that, irrespective of any play which the shaft may have in revolving or reversing, the ring maintains a watertight joint with the end of the tube. As the ring is faced with antifriction metal and well lubricated by oil from the inside, it revolves with the minimum amount of friction. (See facing p. 674).
414	Describe how the stern tube is arranged in the case of twin-screw steamers.	In twin-screw vessels the hull is usually bossed out, port and starboard, to receive the propeller shafting and stern tubes. The tubes are fitted in position from the inside and secured by a collar and nut at the outside, the usual stern bush and other fittings being arranged similarly as in single-screw vessels. The after peak compartments do not extend into the bossed out parts of the hull.

No.	QUESTION.	ANSWER.
415	Explain the term " Conservation of Energy"; also give the measure of mechanical energy and of electrical energy.	By this is meant that energy, like matter, is indestructible, and can only be transformed from one state to another. Energy is said to be wasted or lost in overcoming friction, for example, and this reduces the useful energy of a machine, but the total energy remains the same as originally supplied. A dynamo engine of a certain horsepower transforms mechanical energy into electrical energy, but the amount of electrical energy given out by the dynamo is less than the amount of mechanical energy supplied by the engine, as part of the energy is wasted in overcoming friction, weight, etc. Nevertheless, the sum of the energy wasted and the useful energy given out by the dynamo is equal to the energy originally supplied by the engine, and can be all accounted for. The value of mechanical energy is expressed as 778 foot-lbs. of work to one B.T.U. The value of electrical energy is expressed as one "Joule" or one watt per second, which is equivalent to one "watt hour," that is, one volt and one ampere for the duration of one hour.
416	Explain the application of twisting moments on shafting, and the constant obtained for torsional resistance.	On shafting, the maximum twisting moment is equal to the equation— $$\text{M.T.M.} = \frac{\text{Diameter}^3 \times \text{Stress } \boxed{''}}{5 \cdot 1}$$ The M.T.M. is equal to length of crank multiplied by load on piston, and the constant for torsion is $5 \cdot 1$. $$\text{Diameter of shaft} = \sqrt[3]{\frac{\text{M.T.M.} \times 5 \cdot 1}{\text{Stress } \boxed{''}}}.$$ Note.— As $\dfrac{3 \cdot 1416}{\cdot 7854} = 4$ for area, and diameter $\div 4 =$ mean average of torsional resistance, then, $4 \times 4 = 16$, and $16 \div 3 \cdot 1416 = 5 \cdot 1$ constant.

No.	Question.	Answer.
417	Referring to propellers, give definitions of "pitch," "projected blade area," "developed blade area," and "slip." Give a rule to calculate the apparent slip of a propeller.	By "pitch" of a propeller is meant the advance of the screw per revolution of working in, say, a solid nut. By "projected area" is meant the actual blade area visible when looking from aft forwards, and which constitutes the effective thrusting surface of the propeller.

By "developed area" is meant the area of the blades when flattened out into plane surfaces.

By "slip" is meant the loss of progress due to the water giving way or yielding to the blade pressure. Apparent slip per cent. is calculated as follows :—

$$\frac{\text{Pitch} \times \text{Revolutions} \times 60}{6080} = \text{Engine speed.}$$

Then,   Apparent slip =
$$\frac{(\text{Engine speed} - \text{Ship speed}) \times 100 \text{ per cent.}}{\text{Engine speed}}$$
= per cent.

No.	Question.	Answer.
418	Mention the stresses set up in a vessel's hull when "hogging" or "sagging" in a heavy seaway ; also state how the machinery is affected.	The principal stresses set up in the hull and machinery of a vessel at sea are tension and compression.

When "hogging" occurs the deck plates, beams, etc., are in a state of tension due to the bending moments set up, while the lower parts are under compression.

When sagging takes place the stresses are reversed, the upper parts of the vessel being then under compression and the lower parts under tensile stresses. The rivets are subject to severe shearing stresses. The engine seating will also be subject to tensile and compressive stresses and the line shafting will be affected by stresses produced by the bending moments set up.

No.	Question.	Answer.
419	Compare the advantage of solid and hollow shafting.	The strength of a **solid shaft** varies as the cube of its diameter, therefore the comparative strength of two shafts of, say, 8 in. diameter and 10 in. diameter will be—
		$$\frac{\text{Dia.}^3}{\text{Dia.}^3} = \frac{10}{8^3} = \text{Ratio of strengths} = \text{as } 1 : 1.95.$$
		A **hollow shaft** is stronger than a solid one of the **same sectional area**, as, the diameter being greater, the leverage of the power acting to twist it is less in proportion.
		In addition to this, the removal of the central core of metal reduces the risks of flaws, which often develop at the centre and then extend outwards. Internal inspection for flaws is also to some degree possible.
		Note.—The torsional stress is o at the centre of a shaft, and increases from that point out to the circumference ; the mean stress may therefore be taken as acting at a leverage of half of the shaft radius, or one-fourth of the shaft diameter.
		The strength of a hollow shaft varies as
		$$\frac{D^4 - d^4}{D} \qquad \begin{array}{l} D = \text{outer diameter.} \\ d = \text{inner} \quad\text{,,} \end{array}$$
420	What is meant by the expression "maximum twisting moment," referring to shafts? Also give an expression from which the torsional stress on shafting may be ascertained.	Maximum twisting moment (T.M.) occurs when the crank and the connecting rod form an angle of 90° to each other, and is determined by multiplying the thrust on the connecting rod by the length of the crank.
		Example.—Thrust on connecting rod $= 375000$ lbs., and stroke $= 42$ in.
		Then,
		Max. T.M. $= 375000 \times 21$ in. $= 7875000$ in.-lbs.
		Note.—42 in. $\div 2 = 21$ in. length of crank.
		The torsional resistance stress of shafting is obtained as follows :—
		$$5.1 \times \text{T.M.} = \text{dia.}^3 \times \text{stress } \boxed{''}$$
		Then, Stress $\boxed{''} = \dfrac{5.1 \times \text{T.M.}}{\text{dia.}^3}$
		Note.—5.1 = constant for torsional stress.

No.	Question.	Answer.
421	Referring to deep tanks. If one tank is partly filled and the adjacent tank contains cargo, what precautions are taken to prevent water from leaking back and damaging the cargo?	By the fitting of a ring flange and a blind flange to the pump suction valve chest, so that with cargo in one tank and water in the other the blind flange can be used to prevent water leaking back.
422	Describe arrangement for pumping out bilges, in the case of cellular double-bottom ships. What precautions are taken for preventing sea water from tank-filling pipes entering bilges?	The usual connections for pumping out bilges are : Motor-driven double-acting pumps, with suitable connections to port and starboard bilges. In some cases a centre well is formed, with drain pipes from sides leading into it ; also, a Downton hand pump, worked from the deck, is sometimes fitted for use in case of emergencies. Non-return valves are fitted to bilge-pipe connections.
423	Tail end shaft : how propeller is fixed. Mention nature of stresses on shaft.	The propeller is forced on to a tapered part of the shaft fitted with a feather, and a round nut is screwed on at the after end and locked in position. The propeller shaft is subjected to combined torsional and bending stresses, and for this reason is made heavier than the tunnel lengths of shafting. (See p. 551.)
424	Describe how to test for shaft alignment and wear down.	Wear down of shafting can be tested by means of (a) a bridge gauge, (b) by measuring between the coupling faces, top and bottom, with the bolts slackened or removed, and (c) by means of a "clock" gauge. (See p. 540.) Wear down can also be tested by means of sighting strips and a light. See p. 835, also facing p. 1054.

No.	QUESTION.	ANSWER.
425	Referring to shafting, what is meant by the term "critical speed"? What danger attaches to running the engine at the revolutions corresponding with the critical speed?	By critical speed is meant that revolution speed at which the firing impulses of the engine cylinders coincide with the natural torsional vibrations of the shaft due to inertia forces, and when this occurs the shaft is in serious danger of being fractured by the abnormal stresses set up. The revolution speeds at which shaft torsional vibrations are excessive are known as "critical" or "synchronous" speeds, and these depend on the number of impulses per minute, the weight and elasticity of the revolving parts, and the position of these on the shaft length. Engines should be run at revolution speeds either below or above that of the critical speeds, and in some cases these speeds are marked on a plate fixed at the starting handles, to serve as a guide to the engineer officer on watch.

It should be noted that "critical" speed is independent of the load on the engine, and it may occur at low revolution speed or at high revolution speed.

In a case from practice, the engine consisting of a 2-cycle 6-cylinder set, the critical speeds are marked as 33 revs., 50 revs., and 116 revs. per min., the engineers being instructed to run at 3 revs. lower or 3 revs. higher than the speeds given as "critical."

No.	QUESTION.	ANSWER.
426	Describe a CO_2 refrigerating machine, and the action of same.	Under atmospheric pressure CO_2 evaporates from the liquid state at the particularly low temperature of 120° F. below zero, or 152° below the freezing point of water. In J. & E. Hall's refrigerating machine, however, it is caused to evaporate at only a few degrees below the temperature of the material which it is desired to cool, the principle of the machine being exactly the same as that of machines using anhydrous ammonia on the compression system—viz., as water boils at 212° F. under atmospheric pressure, and about 250° F. at 15 lbs. pressure, fire being usually the source of heat, so liquid carbonic acid boils or vaporises at 30° F. at 35 atmospheres' pressure, and thus permits cold

No.	QUESTION.	ANSWER.
426	*—Continued.*	water or colder brine to be the source from which the necessary heat to boil it is absorbed, exactly in the same manner as the heat of the fire is absorbed in boiling water.
		The compressor draws the gas or vapour from the evaporator and compresses it to the liquefying pressure, which is controlled within certain limits by the temperature of the cooling water. The heat due to compression is absorbed by the cooling water in the condenser, the gas circulating within the condenser coils and becoming liquefied by the time it reaches the lower extremity of these coils.
		By regulating the pressure in the evaporator, the liquid is caused to boil throughout the coils of the evaporator, which act in the same manner as the heating surface in a steam boiler, and the temperature or boiling point of the liquid carbonic acid adjusts itself to that of the source of heat which is causing it to boil, whether it be water at 70° to be reduced to 40°, or brine to be maintained at + 10° F. or − 10° F.
		The surfaces of the evaporator coils are so proportioned that all the liquid which enters at the lower end of the coil is evaporated by the time it reaches the top end, and thus the maximum efficiency is obtained. The compressor then draws in only gas, and compresses it up again to the pressure necessary to liquefy it, and delivers it warm to the condensing coils to continue the cycle of operation.
		The vertical marine type engine consists of a single vertical steam cylinder, with the compressor arranged alongside of it, both secured to a casting containing the condenser coils, which are made of copper, and behind this casting is another secured to it containing the evaporator coils, the whole making a very compact and accessible design.
		See facing p. 1054.

No.	QUESTION.	ANSWER.
427	Describe a pyro-meter.	

No. 462.—Thermo-Couple Pyrometer.

1, Rod of copper.
2, Rod of constantan (copper nickel alloy).
3, Joint between hot ends of couple.
4, Pyrometer case.
5, 6, Terminals for couple at cold ends of rods.
7, Head of pyrometer.
8, Positive wire from copper rod to temperature meter.
9, Negative wire from constantan rod to temperature meter.
10, 11, Terminals at galvanometer type temperature meter.
12, Galvanometer type temperature meter.

UPTAKE

FAH

When the rods are raised in temperature at the brazed end, a low electrical difference of potential is set up between the two, and·this can be arranged to record as temperature difference between the cold and the heated ends.

A magnifying galvanometer is connected up by wires to the two rods, and, as already stated, the electrical difference set up is read off in terms of degrees temperature.

No.	Question.	Answer.
428	What appliance is fitted to supply boilers with fresh water? Also describe a distiller.	An evaporator is employed to produce fresh feed water for boilers.
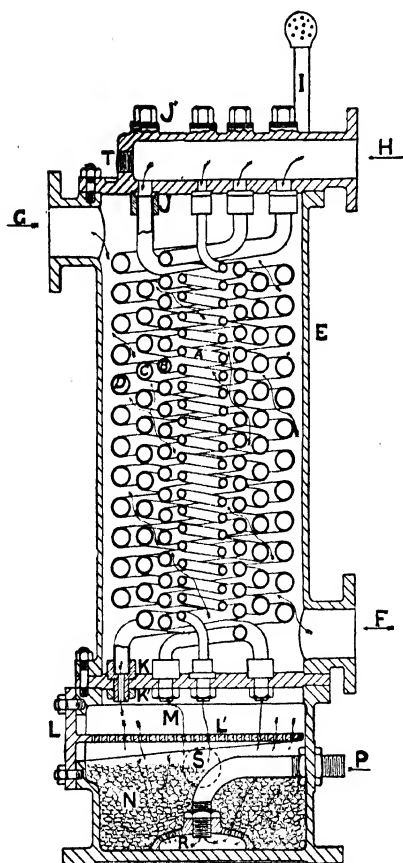
No. 463.—The "Davie" Patent Low Pressure Distiller.

(To work at 20 to 25 lbs. pressure.)

E, Casing.
F, Cooling water inlet.
G, Cooling water outlet.
H, L.P. steam inlet.
I, Air pipe.
K and K', Bottom coil ends and nuts for connection to casing.
L and L', Door and rose plate combined.
M, Filter casing.
N, Filtering media.
P, Outlet for fresh water, screwed Whitworth gas thread.
R, Rose on end of pipe of F.W. outlet.
S, Test cock.
T, H.P. steam connection, if required.

Operation of the Distiller.

A distiller is used for the purpose of obtaining fresh water suitable for drinking purposes, and its operation is as follows : Steam from either the donkey boiler or evaporator passes through the copper coils A and B and is condensed by cold sea water flowing over the coils, the water being usually supplied by the sanitary pump.

The steam thus condensed drains to the bottom as fresh water, and after passing through the filtering medium enters the fresh water tank. An air pipe is also fitted with a perforated ball top to allow of the admission of air, without which the quality of the water as required for drinking purposes would be affected detrimentally.

No.	Question.	Answer.
429	What is absolute temperature? Explain how to calculate the same.	
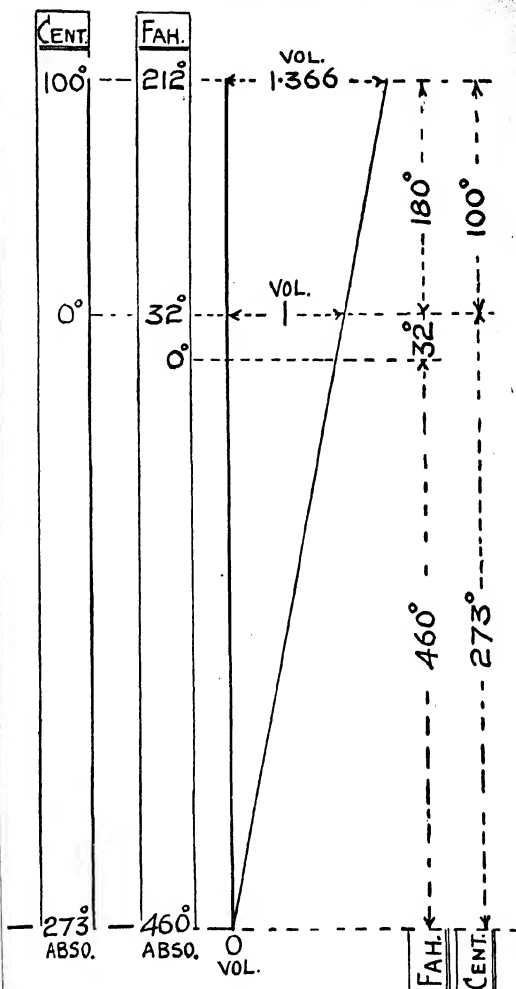
This calculation is based on the fact that atmospheric air expands ·366 of its volume on being heated from 32° to 212° F. It can therefore be assumed that inversely, if all possible heat were withdrawn, the volume of the air would shrink to zero.

Now,   Volume of air at   32° = 1.
                 ,,   ,,   212° = 1·366.

Then,   Increase = 1·366 − 1 = ·366.
And   Increase of temperature = 212° − 32°
               = 180°.

Then,   As ·366 : 1 :: 180 : 492° (below 32°) F.
So that

Absolute temperature below zero of Fahrenheit = 492° − 32° = − 460°.
Again,
    As ·366 : 1 :: 100 : 273° C. absolute.

No.	Question.	Answer.
430	What are keelsons, garboard strakes, sheer strakes, tank marginal plates, stingers, etc. ?	

1, Sheer strake of plates.
2, Beams.
3, Beam knees.
4, Frames.
5, Side strake of plates.
6, Frame stringer angle.
7, Stringer angle.
8, Stringer plate.
9, Bilge strake.
10, Bilge keel.

11, Tank margin bracket.
12, Tank margin plate.
13, Intercostals or "Longitudinals."
14, Flat keel plate.
15, Floors.
16, Garboard strake.
17, Keelson, or centre through plate.
18, Tank top.
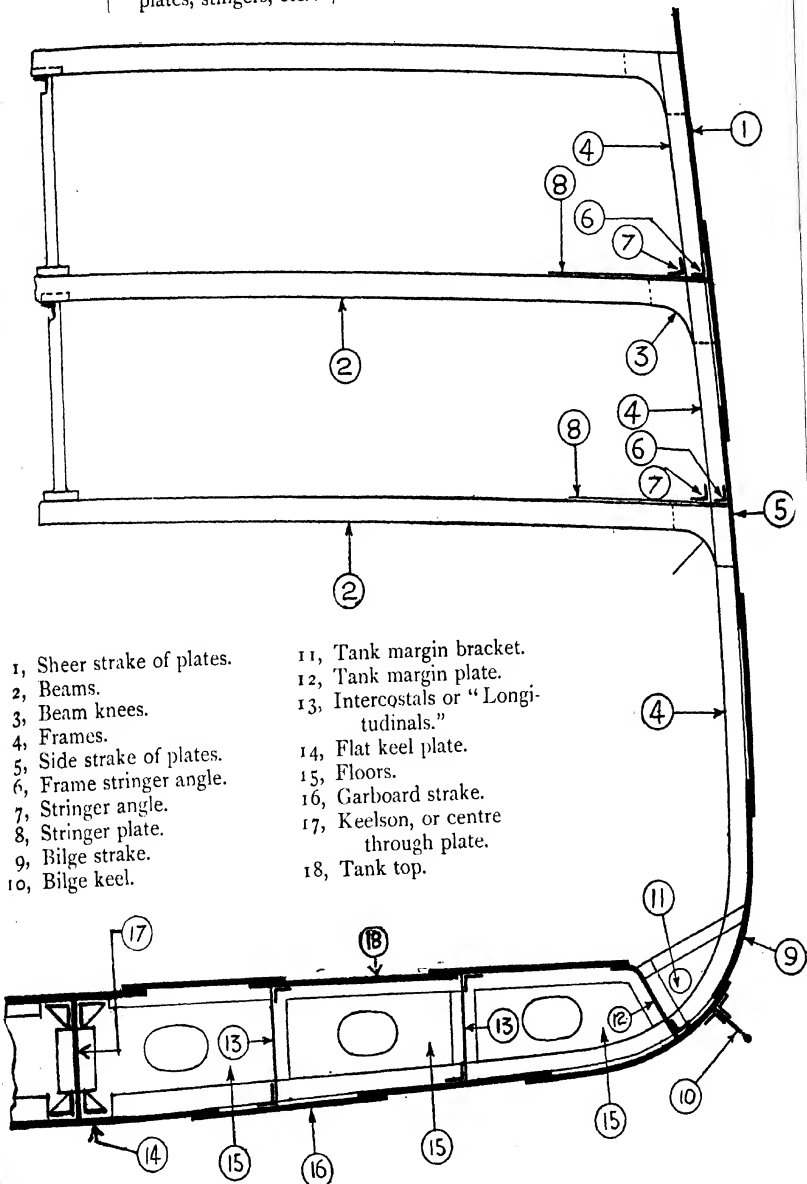
No. 464.—Ship Construction.

No.	Question.	Answer.
430(a)	Describe how the rudder is connected to the ship's hull. What are pintles and gudgeons?	

No. 465.—Rudder.

1. Stern frame.
2. Rudder stock.
3. Bolted and keyed joint.
4. Gudgeons.
5. Pintles.
6. Brass bush.
7. Brass bush.
8. Hard steel coned disc.
9. Hole to allow of expulsion of steel disc when worn.
10. Rudder arms.

The top pintle is provided with a head, and is known as the "locking pintle." This provision prevents the rudder from being lifted out of position by the action of heavy seas.

Note.—The clearance allowed at the pintles and gudgeons for wear down averages about $\frac{3}{4}''$.

No.	Question.	Answer.
431	Referring to steering gear, sketch out or describe an arrangement which acts to prevent heavy shocks on the rudder from being transmitted to the engine and gear.	
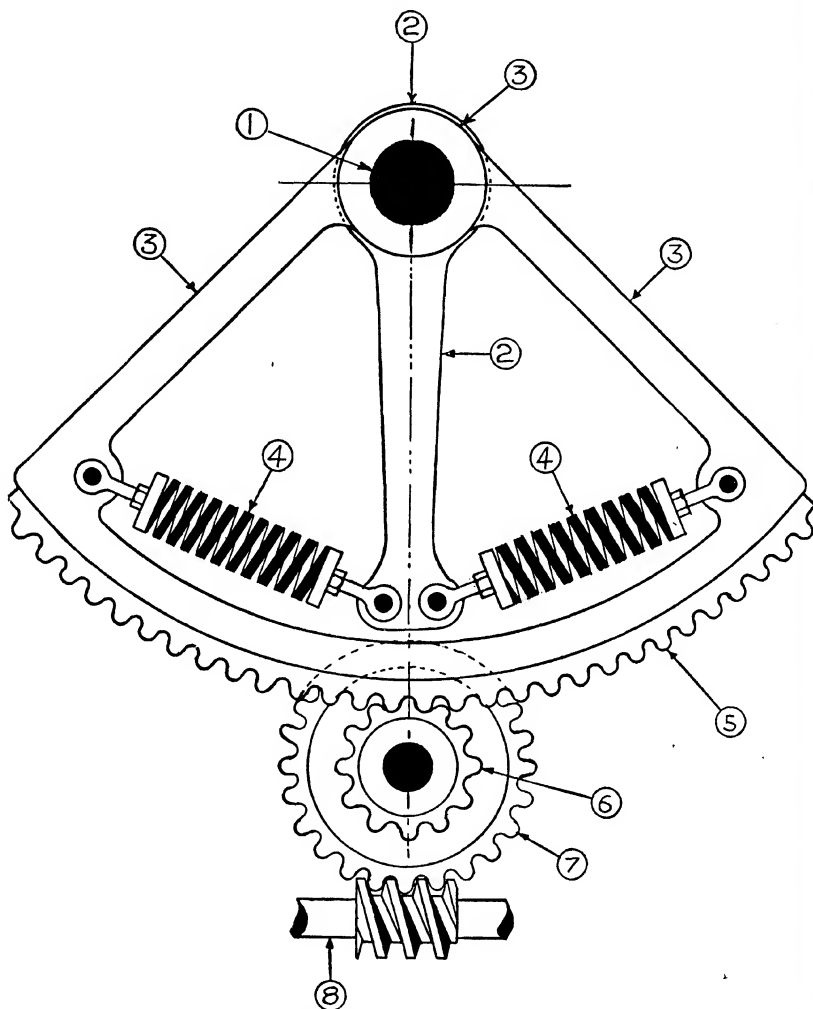
No. 466.—Shock Absorber Springs for Steering Gear.

1, Rudder stock or head.
2, Tiller keyed to rudder stock.
3, Rudder quadrant, *free* on rudder stock.
4, Heavy springs (in compression) to either transmit power or absorb shock, as required.

5, Teeth of quadrant rack.
6, Teeth of gear wheel driven by steering engine through worm wheel 7.
7, Worm wheel.
8, Worm of engine shaft.

432 | Describe pipes and connections for filling and pumping out double bottoms. Where are air and sounding pipes fitted? How is air extracted, and how is all the water extracted when pumping?
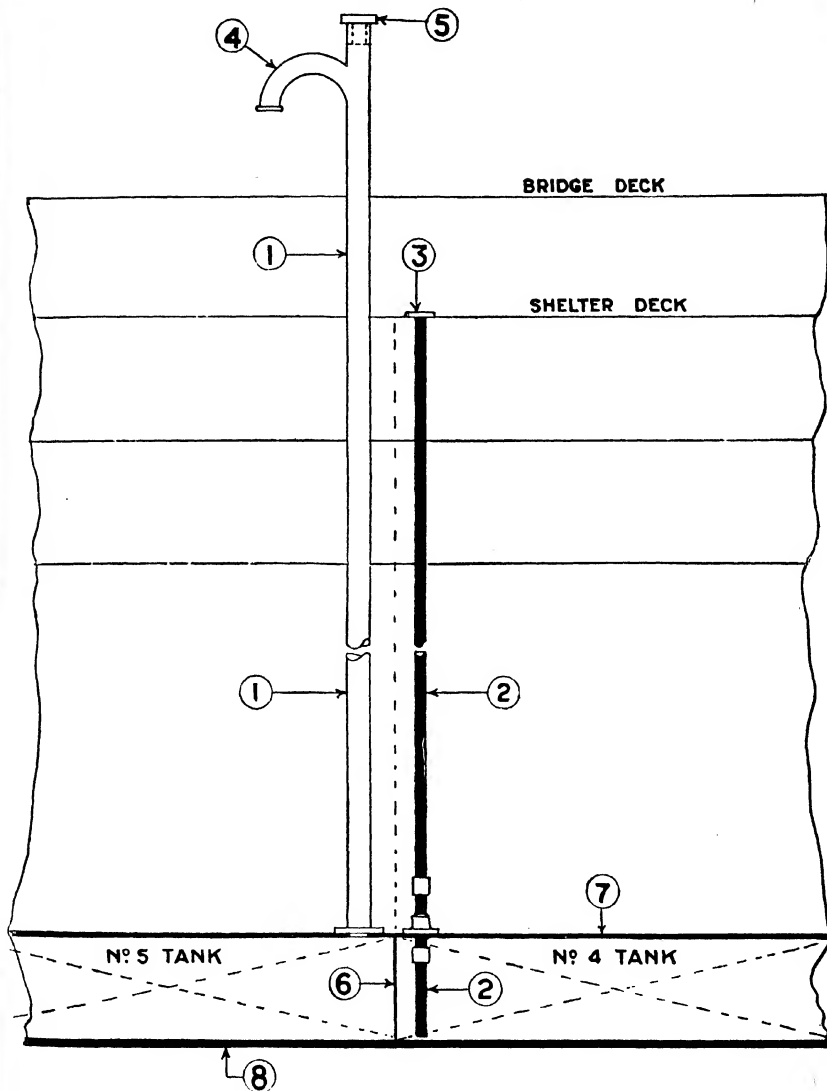
No. 467.—Air Pipes and Sounding Pipes.

1, Air pipe (4 in. dia.), also filling pipe.
2, Sounding pipe (1½ in. dia.).
3, Screwed cap.
4, Swan neck for air escape.

5, Screw cap (for fresh water filling of tanks).
6, Tank division plate.
7, Tank top.
8, Ship's skin.

Note.—In each tank the air pipes are usually placed forward, and the sounding pipes aft, for the reason that air rises to the highest level and water falls to the lowest level.

No.	QUESTION.	ANSWER.
433	Describe or sketch the steering gear from bridge to rudder.	

No. 468.—Modern Type Steering Gear, with Double Drum and Direct Leads.

1, Vertical shaft from steering wheel gearing by bevel wheels with control valve lever. 2, Engine worm. 3, Worm wheel on drum shaft (keyed and bolted). 4, Hunting or return wheel from worm wheel to control valve. 5, Coupling (one on either side). 6, Port chain drum. 7, Starboard chain drum. 8, End bearing.

Note.—As the chain coils round one drum it uncoils on the other drum.

CONTROL VALVE

SHAFT.

| 434 | Explain the term "Joule's equivalent of heat." What is its value and how is it determined? | |
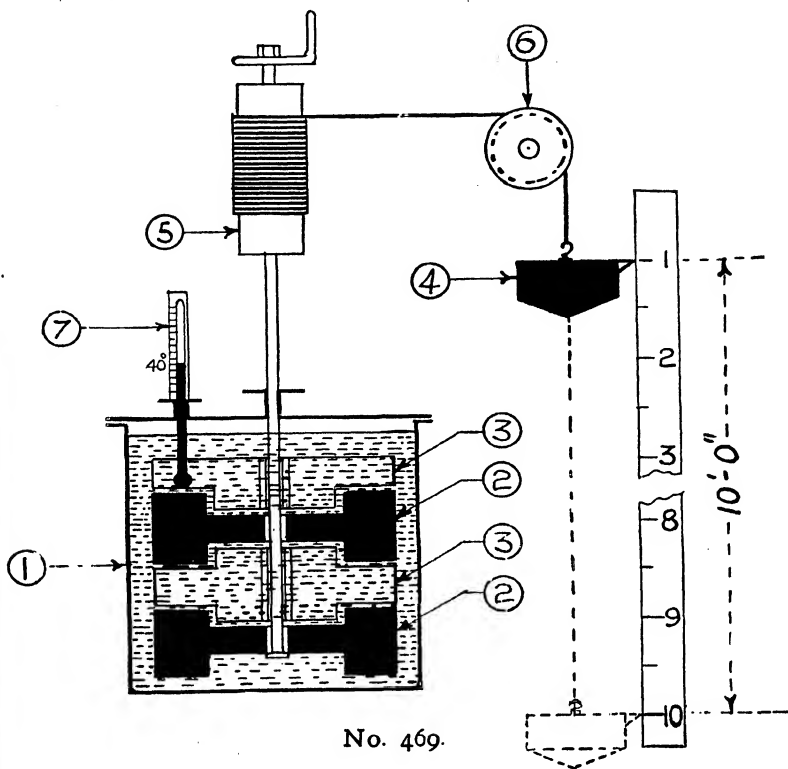
No. 469.
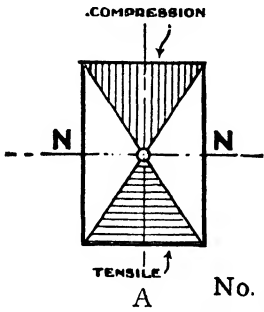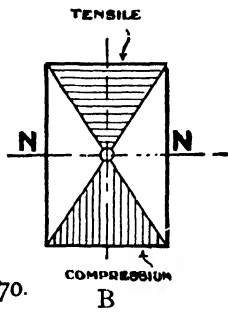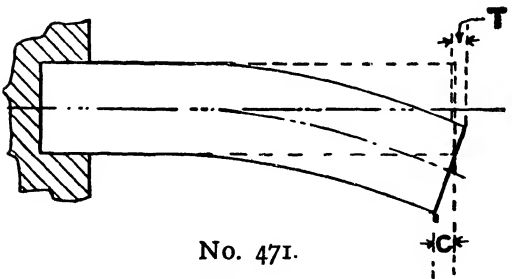
1, Insulated vessel containing 1 lb. of water at 40° temperature F.
2, Revolving paddles.
3, Stationary paddles.
4, Weight of 77·8 lbs.
5, Drum with rope led over pulley to weight.
6, Pulley.
7, Thermometer.
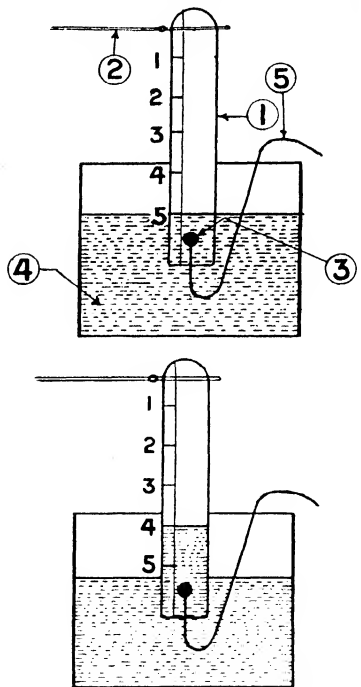
When the weight is set free and falls through a distance of 10 ft., as shown, the water will rise 1° in temperature.
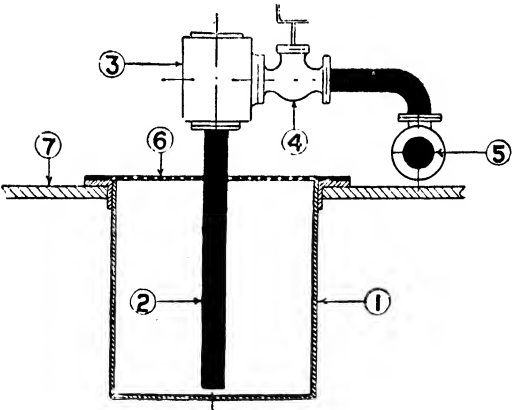
So that 77·8 lbs. × 10 ft. = 778 ft.-lbs. of **work = 1 B.T.U.**

It may thus be expressed that the mechanical equivalent of heat is the work required to raise the temperature of 1 lb. of fresh water at 40° to 41°.

Note.—1° F. and 1 B.T.U. are approximately of the same value when referred to the heating of fresh water.

No.	QUESTION.	ANSWER.
435	Mention stresses set up in beams, also explanation of " neutral axis."	

No. 470.

A

B

N, Neutral axis.
A, Stresses for beam supported at either end.
B, Stresses for cantilever.

In the case of A the upper half fibres of the beam are in compression and the lower half in tension, the neutral axis plane N separating the two. The stresses mentioned increase from zero at the neutral axis line to a maximum at the outer fibres.

In the case of B the stresses are reversed, the upper half being in tension and the lower half in compression.

No. 471.

T = Tension.
C = Compression.

Observe that the upper edge of the beam line is lengthened, giving a tensile stress, and the lower edge is shortened, giving a compressive stress, but that the neutral axis line remains the same length as before, and is therefore unaffected.

No.	QUESTION.	ANSWER.
436	Describe an experiment to prove the relative volumes of Nitrogen and Oxygen in atmospheric air.	Invert a test tube over a vessel containing water, so that the water level inside the tube is at the mark (5) to commence with. Now fix a small pellet of pure phosphorus on the end of a wire, and quickly place it inside the test tube as shown (first sketch). In due time it will be observed that the water has risen through one division and will now be at mark (4) (second sketch), the reason being that the pellet of phosphorus has absorbed the oxygen present ($\frac{1}{5}$ volume), and that only nitrogen is left ($\frac{4}{5}$).

Atmospheric air is therefore said to consist of about one volume of oxygen to four volumes of nitrogen.

No. 472.

1, Test tube marked off into divisions.
2, Supporting wire.
3, Pellet of phosphorus.
4, Water.
5, Wire holding phosphorus pellet in position.

No.	QUESTION.	ANSWER.
437	Describe the arrangement of a centre well between the tanks, also the provision that is made for pumping out such bilges ; also show by sketch how water gets into the well.	

No. 473.—"Hat Box" Drain Well.

1, Drain well.
2, Bilge suction pipe ($3\frac{1}{2}$ in. dia.).
3, Mud box.
4, N.R. screw-down valve.
5, Main bilge pipe line (5 in. dia.).
6, Perforated plate.
7, Tank top.

No.	QUESTION.	ANSWER.
438	Describe or sketch out a micrometer gauge.	
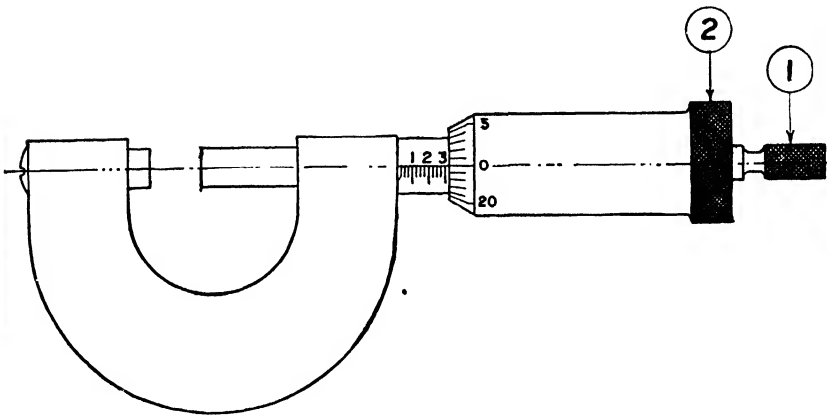
No. 476.

1, Thimble for screwing up spindle.

2, Drum divided circumferentially into twenty-five divisions.

Each turn of the spindle is equal to $\frac{25}{1000}$ in., and as each inch in length is divided up into tenths, and each equal tenth into *four* screws or turns,

Then, $4 \times \frac{25''}{1000} = \frac{100''}{1000}$ per tenth inch.

The drum being divided into twenty-five divisions, each one is therefore equal to $\frac{1}{1000}$ in.

No.	QUESTION.	ANSWER.
439	Describe Bourdon and Schaffer pressure gauges.	**Bourdon Gauge.** The internal construction consists of a tube of oval section, which, under the influence of pressure, tends to become circular in section, and in doing so the tube length acts to straighten out. The closed end of the tube being connected to a hinged toothed quadrant, acts on the pinion of the dial pointer and in this way registers the pressure. **Schaffer Gauge.** The corrugated steel plate lifts with increase of pressure and actuates the pointer through the rod and hinged rack.
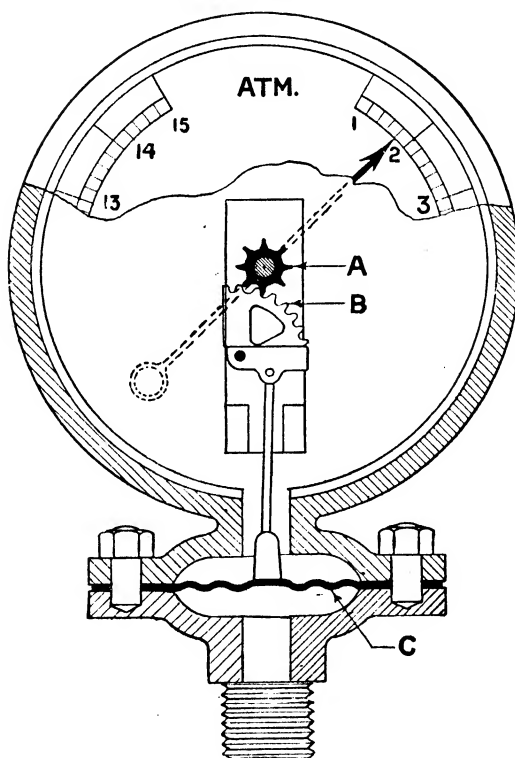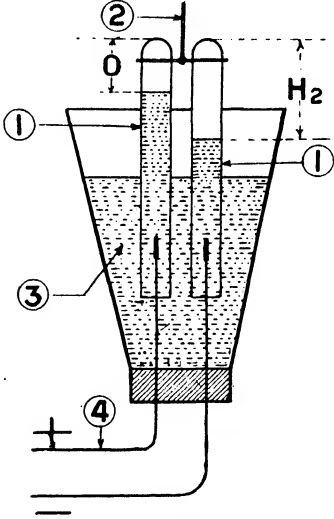
No. 477.—Schaffer Pressure Gauge.

A, Toothed pinion on pointer.　　B, Toothed rack of quadrant.
C, Corrugated flexible steel disc.

No.	QUESTION.	ANSWER.
440	State the chemical composition of water, and describe an experiment to prove this to be the case.	Fill two test tubes with fresh water and suspend these, as shown, inside a glass vessel partly filled up with acidulated water. Pass the wires from a 4-volt battery through the stopper of the vessel and lead the ends inside the test tubes, first tipping them with pieces of platinum foil. When the current from the battery is switched on, decomposition of the water takes place, and in due time it will be found that the test tube with the positive wire contains a certain volume of oxygen gas, while the other will contain hydrogen gas of double the volume. Water, therefore, consists by volume of hydrogen two parts and oxygen one part, or, as it is usually expressed, H_2O.

No. 478.

1, Test tubes containing water.
2, Supporting wire.
3, Weak acid solution.
4, Positive wire from 4-volt battery.
O = Oxygen, one volume.
H = Hydrogen, two volumes.

METALS

No.	Question.	Answer.
441	Discriminate between mass, weight, density, and specific gravity of a body.	**Mass.**—By this is meant the quantity of matter contained in a body when referred to a piece of platinum which is retained for reference in the Exchequer Office in London, the piece of platinum representing the standard British weight of 1 lb. In engineering theory and practice the term "mass of 1 lb." may be taken to mean weight of 1 lb. **Weight.**—Is a measure of the attraction of the earth towards bodies, as shown by a spring balance. It varies with the value of the acceleration due to gravity, which is usually taken as 32·2 ft. per sec. per sec. **Density.**—Given two bodies of equal weight, that having the smaller volume possesses the greater density of the two. Take, for example, a pound of pine wood and a pound of lead, then the lead is greater in density than the wood, as the volume is much less. **Specific Gravity.** — Compares the weight of a body to fresh water, of equal volume, and at 60°F.

No.	QUESTION.	ANSWER.
442	Describe the electric system of welding as applied to hull and boiler repairs. Mention the parts suitable for this method of treatment.	Parts of boilers under compression, such as furnaces and combustion chambers, are most suitable for the electric welding process of repair, as the weld will then be kept closed by the compressive stress. Parts of boilers subject to tensile stress, such as, for example, stays and boiler shell plates, are not so suitable for welding, although boiler shells and end plates are often treated in this way after permission is obtained from the Board of Trade. Various systems of electric welding are carried out in practice, and in that of the North British Electric Welding Co. Ltd., of Glasgow, the voltage at the generating dynamo is 60 to 70, dropping to 20 or 25 at the work, and held at this by a suitable resistance coil. The amperes required may be about 150 or thereabout. The electrode or pencil is the positive element of the arc, and it is coated with a special flux, which vaporises and surrounds the mild steel rod as a protective against oxidation when the heat is on and the current flowing. When the welder breaks the arc to, say, hammer in the material just deposited, the current is at once absorbed by a powerful resistance, which falls into circuit by means of a solenoid switch.
443	Describe clearly the difference between the autogenous welding of a material and burning out, such as occurs when cutting a plate with the oxygen jet.	In autogenous welding the material is first fused or melted before the welding is carried out, the temperature applied only being sufficient to reduce the metal to a molten condition. In the cutting through of a plate by oxygen jet, the material is completely burnt out, as combustion or oxidation takes place, the metal at the position of the cut being destroyed chemically.

No.	QUESTION.	ANSWER.
444	Describe the oxy-acetylene process of welding as applied to metals, machinery, hulls of ships, and boilers.	This modern method of repair is often applied to boiler end plates, furnaces, combustion chambers, rivet holes, etc., also to ships' rudder posts, stern posts, etc. The pressure of the oxygen ranges from 5 to 30 lbs. per sq. in. and varies with size of blowpipe. The pressure of the acetylene averages about $\frac{1}{4}$ lb. per sq. in., which is equal to about 8 in. of water on the gauge. Acetylene gas is almost as heavy as atmospheric air, its chemical composition being C_2H_2, and one cubic foot generates about 1500 B.T.U. The temperature of the flame at the blowpipe cone is said to be about 6000° F., and the flame is surrounded by an envelope of hydrogen, which naturally acts as a flux to prevent oxidation of the heated parts. The blowpipe handle is fitted with two valves which separately control the supply of acetylene and oxygen. In applying the blowpipe, it is important that the metal which is to be reinforced or joined should first be reduced to a state of fusion before depositing the welding material, otherwise the weld will be defective. After turning on the gas to the blowpipe, ignition can be obtained by means of a candle flame. The intense heat of the gas issuing from the blowpipe nozzle causes rapid melting of the metal, and, after sufficient fusion is obtained, the rod of welding material is also melted by the blowpipe flame and the welding process carried out. When finishing the weld a few hammer blows are given to the work while the metal is still soft; this tends to compress the welded mass and so increase the density and soundness of the material at the position of the joint.

No.	QUESTION.	ANSWER.
445	Describe the defects which develop in weight-lifting chains and in steering-gear chains; also how they are remedied.	In the case of chains, fatigue of the metals takes place after long service, and the material becomes brittle. To remedy this defect the heat process of annealing is carried out—that is, the chains are heated to a red heat in an annealing furnace and cooled out slowly. This process restores the ductility.
446	What is copper? Where is it used, and why? Give strength of plate copper, bar copper, and annealed copper.	**Copper.**—This metal is very ductile, and is greatly used in conjunction with zinc, tin, and other metals, to form alloys, also for piping and for gas-tight joints:—

	Cast.	Forged.	Rolled.	Copper Wire.		Sheet Copper.
Tensile strength in tons per square inch	10 tons	15 tons	16 tons	28 tons (before annealing)	18 tons (after annealing)	13 tons

No.	QUESTION.	ANSWER.
447	Referring to metals: give definitions of ultimate strength, breaking stress, and yield point.	By this is meant the load per square inch which breaks or completely fractures a material. Ultimate strength is equivalent to breaking stress. For mild steel the breaking stress or ultimate strength ranges from 28 tons to 30 tons per sq. in. Yield point means that point at which the material suddenly breaks down or yields, and this takes place just previous to fracture. For mild steel the yield point is about 22 tons for a breaking load of 28 tons.
448	What is meant by permanent set? If a material is in a condition of permanent set, why is it unsafe for use?	If the elastic limit load of a material is exceeded, permanent set takes place and the metal will then be in a condition of strain. This being the case the material is not reliable, and will be unsafe for use.
449	Describe the manufacture of wrought iron; name parts made of same, and why.	To remove the carbon or graphite the bars of pig iron are broken up and placed in the puddling furnace, which consists of a heavy cast-iron and brickwork structure arranged with a low roof so that the hot gases from the fire on one side will come into close contact with the broken-up pieces of pig iron on the other side. A door is also arranged in the wall to allow the "puddler" to work the heavy iron bar tool employed to stir up the mass and induce the separated iron to adhere into solid masses or balls which are called "blooms." The blooms as they form are removed from the furnace and are put under the steam hammer, after which the process of rolling is carried out in a mill. The wrought-iron metal is afterwards again subjected to rolling, piling, and hammering so as to obtain homogeneity of section, and the more often this is done the better is the quality of the iron obtained.

No.	QUESTION.	ANSWER.
450	What is meant by " Elongation " and " Contraction of Area," referring to test strips of metal under tensile stress ?	
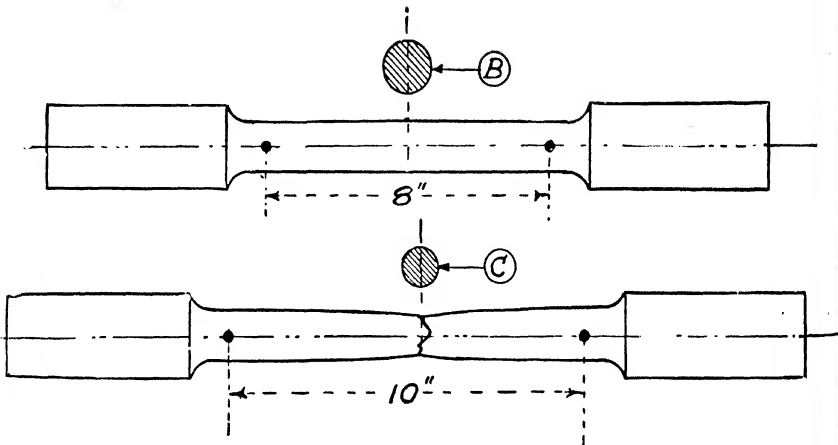
No. 479.—Test Bars.
Tensile Strength.)

In testing mild steel for boiler work, specimen bars, as shown, are placed in the testing machine with punch marks ·placed, say, 8 in. apart.

The load is then applied, and observations made until the bar finally breaks. Suppose that at fracture point the distance between the punch marks has increased to, say, 10 in.

Then,
1. Before Test—
   Length between punch marks = 8″.
   Area of bar B = ·75 $\boxed{n}$.
2. After Test—
   Length between punch marks = 10″.
   Area of bar at fracture C = ·45 $\boxed{n}$.

Then,
Elongation =
$$\frac{(10 - 8) \times 100}{8} = 25 \text{ per cent.}$$

Reduction of Area =
$$\frac{(·75 - ·45) \times 100}{·75} = 40 \text{ per cent.}$$

No.	Question.	Answer.
450	—*Continued.*	Under load stress the following are the points which should be observed and noted :— 1. Permanent set and yield point. 2. Fracture point. 3. Elongation, per cent. 4. Contraction of area, per cent.
451	Describe the processes of steel manufacture. State the difference between acid process and basic process.	**Acid Process** (Bessemer).—For this process of steel manufacture good pig iron free from phosphorus is necessary, and after the iron is melted a blast of air is forced through the molten metal to burn out the various impurities present, such as carbon, silicon, etc., and in this way liberate pure iron. The converter is lined with ganister, which assists in removing impurities present. A measured quantity of carbon and manganese is then added to the molten mass, the air blast is resumed for a short period, and the result is the production of steel. **Basic Process** (Thomas-Gilchrist).—In the "basic" process inferior grades of cheap pig iron containing phosphorus in quantity can be used, as the converter is lined with magnesian limestone ("dolomite"), which absorbs the phosphorus during the roasting process. The air blast, as in the acid process, is employed to burn out the carbon, and at the same time extract the phosphorus, which results in the production of pure iron, after which, as in the acid process, a measured quantity of ferromanganese is added to convert the pure iron into steel, and the air blast is again applied for a few minutes. The molten metal is finally run into ingot moulds. Afterwards, reheating and hammering treatment is carried out as required.

No.	QUESTION.	ANSWER.
452	Mention the physical properties required in metals used for (*a*) Diesel cylinder liners; (*b*) exhaust valves; (*c*) springs; and (*d*) blast air pipes. Name the materials most suitable for each.	For cylinder liners the material required is special heat resisting cast iron with a tensile strength of about 16 tons per ▢. The material employed requires to possess high resistance to heat stresses set up under conditions of temperature difference. Exhaust valve faces should be of cast iron to resist the action of the high exhaust gas temperature. Springs should possess the property of strength, stiffness, and resistance to torque, combined with elasticity. Blast air piping material should be strong in tensile stress and possess sufficient ductility for the purpose. Springs to be of hard steel, and blast air piping also of mild steel.
453	What is Tungsten, Cobalt, and Nickel? High speed steel. How does it differ in composition and properties from ordinary tool steel? How is a tool made from the bar? also, how is it tempered?	Modern machine tool steel, which remains hard even when working at a dull red heat, is termed "high speed steel," and possesses the special property of "red hardness," which allows of an increase in cutting speed of over 300 per cent. High speed steel is a product of the most recent developments in steel manufacture, and the special properties obtained are due to the introduction of rare mineral elements into the composition of ordinary "carbon," or "tool steel." The special elements consist of the following: Tungsten, Nickel, Manganese, Chromium, Cobalt, Vanadium, and Molybdenum, the percentage present ranging from about ·3 to 5·5. A tool is first forged from the bar, shaped, and afterwards tempered, this process consisting of heating up to, say, 800° F., then cooling in oil or water. When tempered the material is softened, and possesses increased toughness.

No.	QUESTION.	ANSWER.
454	Referring to heat treatment of tool steel, describe what is meant by "hardening," "tempering," and "annealing."	**Hardening.** In this process steel is given its maximum hardness by heating to a suitable temperature (about 1250° F.), and then quenching in water or oil. **Tempering.** Tempering reduces the brittleness produced by hardening, and consists of reheating the steel to a much lower temperature (between 400° and 600° F.) than that required for hardening, and then cooling in water, oil, or in air. After tempering, the steel is softer and has acquired toughness. **Annealing.** After forging a steel tool, stresses are set up, and these can be got rid of by the process of annealing, or "normalising," as it is now called. The parts to be treated in this way are packed in a closed airtight box, and the box is then heated to a dull red (about 1500° F.) in a special annealing furnace. After "soaking" for some little time at this temperature the box is withdrawn, and both box and contents are allowed to cool down slowly to atmospheric temperature.
455	Describe how cast iron is obtained, and mention how the engine parts are made, giving the names of same.	Cast iron is obtained by melting bars of pig iron in a "cupola" furnace. This furnace is somewhat similar in construction to that of the blast furnace, but in this case bars of pig iron are arranged alternately between layers of charcoal or coke. After sealing up the bottom door with fireclay the air blast is applied, and after melting the iron is withdrawn by a tapping hole at the bottom into ladles for moulding purposes. For tough castings, pieces of scrap wrought iron are mixed with the pig iron during the melting process. Cylinders, cylinder liners, pistons, bedplates, and engine columns, etc., are usually of cast iron.

No.	QUESTION.	ANSWER.
456	Give definitions of tensile, compressive, torsional, and shearing stresses, with examples of each.	When an applied force tends to lengthen, say, a bar, the stress is said to be of a tensile nature. An example of this occurs in the long stay bolts which connect the cylinders with the bedplate.
		If the applied force tends to shorten a bar the stress is then known as compression. An example of this occurs in the downstroke of the piston rod and connecting rod. When a force tends to twist, say, a shaft, the stress is of a torsional nature. All line shafting is subject to torsional stress. When a force acts to cut through the cross section of a bar or shaft at right angles to the axis line, the stress is of a shearing nature. Rivets, coupling bolts, and crankpins are subject to shearing stresses.
457	What is case hardening, and why done? Which metals is it applied to?	The parts to be case hardened are packed in boxes, containing substances rich in carbon, such as bone dust, charred leather, charcoal, etc., and the bottom of the box is served with a layer of fireclay: the parts are then laid in layers, with layers of carbon substance packed between each.
		The box is then sealed up airtight with fireclay, placed in the furnace and, after heating up to about 1200° F., is kept for some hours at this temperature to allow of the gradual deposit of carbon on the parts requiring treatment.
		After withdrawal from the furnace, the box and its contents are usually plunged into cold water, which has the effect of hardening. Case hardening gives a surface coating of steel on mild steel or iron parts, and after from four to six hours' heating, the skin of steel so formed may be fully $\frac{1}{16}$ in. thick.

No.	Question.	Answer.
458	What is tool steel? How is it made and for what is it used? What kind of steel is employed for punches, shears, knives, chisels, scrapers, drills, and files? Also describe the process of tempering.	In the cementation process pure wrought-iron bars are converted into tool steel by the addition of carbon from coke. Alternate layers of charcoal lumps and iron bars are piled up in the furnace, layer above layer, and the top layer is then sealed up with fireclay, after which heat is applied (1400° F.) and kept up for from ten to fifteen days continuously. The chemical process evolved consists of the absorption of carbon by the iron, which thus changes its condition to that of what is known as "blister" steel. If the cementation process be stopped at various stages of development, steel suitable for springs, scrapers, shears, punches, etc., may be obtained by the further processes of reheating, piling, and hammering. The finest quality of steel is obtained by this process. Tempering (or "letting down") consists in heating the tool to, say, a temperature of 800° F., then cooling out in water or oil. This heat process produces softness and toughness in the material. *Note.*—Cast steel is obtained from blister steel which has been broken up and re-melted in crucibles, and then poured out into ingot form.
459	Cast steel: State where used; also give the tensile strength and elongation per cent.	Cast steel is made from blister steel (cementation process) which has been broken up and re-melted in a closed crucible. The metal is then run out into ingots, and afterwards cast into the required forms. Cast steel is often employed in place of cast iron for columns, bottom ends, bedplates, crossheads, propeller bosses, etc. An objection to this metal is the danger of the castings turning out unsound, especially in the case of large sizes. The tensile strength of good cast steel (which has been annealed after casting) is from 28 to 40 tons, with an elongation of about 16 per cent.

No.	QUESTION.	ANSWER.
460	State the physical properties required in materials which are employed as follows : (*a*) steel for springs ; (*b*) cast iron for Diesel engine cylinder liners and piston rings; (*c*) mild steel for boiler work; (*d*) steel for piston rods and connecting rods; (*e*) cast iron for cylinder columns and bedplates ; (*f*) phosphor bronze for propeller blades ; (*g*) steel for shafting ; (*h*) iron or steel for bolts, studs, and nuts ; (*i*) gun-metal or brass for water pump fittings ; (*k*) copper for steam pipes or coils.	**Steel for Springs** should possess the properties of hardness, strength, resistance to torque, and elasticity (resilience). **Cast Iron** for Diesel engine cylinders and liners should possess properties of hardness, strength, capability of forming a smooth rubbing surface, and ability to resist distortion or cracking from severe heat stresses. **Mild Steel for Boiler Work** should possess properties of strength and ductility. **Steel for Piston Rods and Connecting Rods** should possess high tensile and compressive strengths. **Cast Iron for Columns** should possess high compressive strength and moderate tensile strength, together with rigidity. **Phosphor Bronze** for propeller blades should possess properties of toughness, strength, resistance to corrosion, and ability of developing a smooth skin surface. **Mild Steel** for shafting should possess properties of high tensile strength and ductility, and ability to resist torsional stresses. **Iron or Steel Bolts** should possess properties of strength and toughness or ductility. **Gun-Metal** or brass for pump fitting should possess non-corrosive qualities, combined with toughness and strength. **Copper** for steam pipes or coils should be of maximum strength and possess suitable ductility, also to be free from brittleness.
461	Factor of safety : state how determined, etc.	By " Factor of Safety " is meant the ratio of breaking stress to safe working stress allowed on a material. For dead loads (as occurs in boilerwork), the factor ranges from 4·5 to 6, and for live loads, such as that set up on piston rods, or connecting rods, or main bearing bolts, the factor ranges from 9 to 14. For shafting the factor of safety is about 7.

No.	QUESTION.	ANSWER.
462	What is meant by " brazing " ?	Brazing is hard soldering, and consists of the joining together of parts made of copper or brass, such as, for example, a brass flange to a copper pipe. The pieces to be joined are first carefully cleaned, then fitted in place and clamped together in the required position, and, after they have been covered over with spelter (composed of one part copper and one part zinc), heat is applied by means of a charcoal fire, and the spelter runs into the spaces of the joint. Borax is sprinkled over the parts as a flux to make the spelter run easily. After cooling, the spelter sets hard and the parts are then firmly soldered together. *Note.*—Soft solder is made up of equal parts of tin and lead, resin or spirits of salts being employed as a flux.
463	What is meant by " welding " ?	In welding, two pieces of steel are joined by being first heated to about 1600° F. (white heat) and then hammered together. The ends to be joined require to be scarfed or tapered away at an angle, and before putting the two surfaces together sand (if iron) or borax (if steel) is sprinkled over them as a flux, and the hammering proceeded with. It is important that the two pieces be heated to as nearly the same temperature as possible before joining. *Note.*—The flux (sand or borax) acts to clean the surfaces of the magnetic oxide which forms on the heated surfaces, and which would otherwise prevent perfect adhesion.

No.	QUESTION.	ANSWER.
464	Describe briefly the turbo-electric drive, and mention the advantages claimed by this system of propulsion.	This arrangement consists of turbines driving an electrical generator, which in turn supplies current to a reversible electrical motor either coupled direct or through gearing to the propeller shaft. The turbines and generator run at high revolution speed and the motor at low revolution speed, and in this way combine maximum turbine and propeller efficiencies. The driving motor is usually placed right aft and considerable saving in cargo or passenger space can be effected. By the electrical drive greater flexibility of power is obtained, and as the turbine requires to run in one direction only, stopping and starting losses are eliminated. An important advantage obtained is that of economy at low powers, as the fuel consumption per H.P. per hour is the same for all powers, low or high. As previously mentioned, astern turbines are eliminated, the driving electrical motor being reversible.
465	How is reversing carried out in a large marine Diesel engine ? Is it practicable to put the engine from full ahead to full astern without first shutting off the fuel ?	See pp. 62, 183. If it were possible to put the reversing gear over from, say, ahead to astern without shutting off the fuel, a serious explosion might happen owing to fuel having been admitted to the cylinders during the wrong valve timing position of the stroke.
466	Describe an all electric steering gear ; also explain how it is controlled.	See p. 971-973.

No.	QUESTION.	ANSWER.
467	State the calorific value of the fuel oils used for Diesel engines. What is the heat percentage doing useful work and where does the rest of the heat go? State the percentage of each.	The average calorific value of good *Diesel engine fuel oil is about 18800 B.T U.'s per lb.* The heat expended is accounted for as follows :— Brake thermal efficiency (useful work) - - = 33 per cent. Heat rejected in cooling water - - - = 30 ,, Heat rejected in exhaust gases - - - = 25 ,, Heat rejected in friction, radiation, etc. - - = 12 ,, ————— 100 ,,
468	Referring to the consumption of fuel per B H.P per hour of two ships, one driven by steam with oil fired boilers, and the other by Diesel engines; give data showing the respective running costs of each, assuming equal power for each ship.	Assume, say, 2000 B.H.P. for each, and oil fuel consumption of 1·2 lbs. per B.H.P. per hour for the steam engined vessel against ·42 in the Diesel engined vessel. Then, (1) Steam— $$\frac{2000 \times 1\cdot2 \times 24}{2240} = 25\cdot71 \text{ tons per 24 hrs.}$$ (2) Diesel— $$\frac{2000 \times \cdot42 \times 24}{2240} = 9 \text{ tons per 24 hrs.}$$ Assume cost of oil = 75 shillings per ton. Then, $\frac{25\cdot71 \times 75}{20} = £96.$ 8s. 3d. And, $\frac{9 \times 75}{20} = £33.$ 15s. Difference = £62. 12s. 9d. saved per 24 hours by use of Diesel engines. As regards the wages bill of the engine-room staff in each case, it may be stated that although the scale of pays obtaining in Diesel practice is higher than that for steam, the Diesel ship can, in most cases, be operated by a smaller staff, as the boiler-room staff is entirely eliminated. *Note.*—The cost of lubricating oil would be much more in the case of Diesel machinery.

No.	QUESTION.	ANSWER.
469	What effect would excessive clearance have on a Diesel engine and on a steam engine ? State the diameter of cylinder and stroke of the engine on your last ship. What was the cylinder volume and what would be the corresponding clearance volume ?	In Diesel engine practice excessive clearance volume would result in loss of thermal efficiency, as the reduced compression ratio would lower the pressure and temperature of the compressed suction air, making firing more difficult. In steam practice excessive clearance volume would reduce the compression and raise slightly the terminal expansion pressure ; the thermal efficiency would be lowered and the consumption increased. Diameter of cylinders of Diesel engines of last vessel was 28 in. and stroke 30 in., with a mean lineal clearance of 2·4 in., which gives a clearance volume of 8 per cent., as shown by the working below. Clearance volume $=\dfrac{28^2 \times 2\cdot4 \times 100}{28^2 \times 30}=8$ per cent.
470	Describe briefly the Diesel electric drive, and mention the advantages claimed by this system of propulsion. What kind of dynamos are employed ?	In this system of propulsion, one or more Diesel engine sets are coupled direct to powerful D.C. electrical generators, which supply current to a reversible double armature motor which is coupled direct to the propeller shaft. As the tunnel shafting is done away with, considerable space is therefore saved for cargo purposes, and, among other advantages, great flexibility of power is claimed ; stopping and starting losses are also eliminated. As the engines are divided up into four separate units of equal power, one, two, three, or four engines can be run as required by the power conditions obtaining. It will therefore be evident that the fuel consumption per B.H.P. will be no more when running at low powers than at full powers. Direct current is usually employed, the voltage being 220 ; the Diesel

NO.	QUESTION.	ANSWER.
470	—Continued.	engine and generator revolution speed being 250, and the propeller shaft speed 90 revs. per min.

ENGINE ROOM

MOTOR ROOM
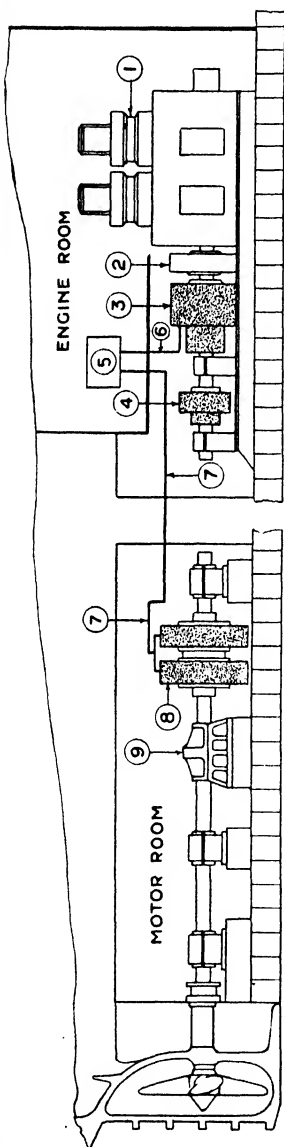
No. 480.—Diesel Electric Drive as fitted to Vessels of the U.S. Fruit Co. Ltd.*

(Electrical gear by Messrs The British Thomson-Houston Co. Ltd., Rugby.)

* The author is indebted to Messrs The British Thomson-Houston Co. Ltd. for information referring to Diesel Electric Drives.

1, Two-cylinder Cammell-Fullagar Diesel engine of 750 B.H.P. running at 250 revs. per min., four of these sets being fitted.

2, Flywheel.

3, Main electrical D.C. generator of 500 kw. output at 220 volts.

4, Auxiliary electrical D.C. generator of 200 kw. output at 220 volts.

5, Control panel.

6, Cables from main generator to control panel.

7, Cables from control panel to 2500 H.P. reversible and double armature motor, coupled direct to the propeller shaft, and running at 90 revs. per min.

8, Reversible double armature motor.

9, Michell thrust.

No.	Question.	Answer.
471	Explain how the fuel admission is regulated in the case of a Werkspoor Diesel engine.	In the Werkspoor patent system of oil fuel feed (see No. 90, p. 138), the oil is fed to the cylinder fuel valves by gravity from a floating vessel which is balanced by a counterweight. The fuel is pumped into this vessel by a high pressure fuel pump, and as soon as the amount of fuel exceeds a certain weight, the floating vessel tips the balance, and by this movement shuts off the fuel supply to the high pressure fuel pump. To balance the injection air pressure in the cylinder fuel valves, injection air is admitted to the top of the floating vessel, which is mounted at a certain height above the cylinder, so that the fuel flows regularly to the cylinder valves due to the head, which is automatically maintained. In flowing from the floating vessel the fuel passes through an Aspinall governor valve, hand operated throttle valve, and finally through a distributing box fitted with a regulating valve for each cylinder. This arrangement has several advantages. It does away with six small fuel pumps with a large number of small valves and working parts, and substitutes a single large pump of substantial size. It is also possible on this system to provide a spare pump. A certain amount of fuel is always on hand, and even if the pump should fail, the engine will work long enough on the contents of the floating vessel to enable the engineers to start up the stand-by pump.
472	Make a diagrammatic sketch of a Beardmore - Tosi Diesel engine.	
473	Make a sketch of a Beardmore - Tosi director valve.	

No.	QUESTION.	ANSWER.
474	State the composition of boiler scale, and explain the difference between scale, salt precipitation, and density.	Boiler scale formed from sea water feed consists of about 85 per cent. lime sulphate and one per cent. lime carbonate, the remainder being organic matter, etc. Lime sulphate deposits at temperatures over 267° F. · Lime carbonate deposits at temperatures over 212° F. Scale formed from fresh water feed consists of about 75 per cent. lime carbonate and $3\frac{1}{2}$ per cent. lime sulphate. Precipitation of salt occurs when the boiler density exceeds the saturation limit of 35 oz. per gal., and this is independent of temperature. Heat is the cause of scale deposit, whereas density is the cause of salt deposit.
475	Describe the construction of a three-stage air compressor piston, and explain how the piston rings are machined.	In a three-stage air compressor the stages are usually arranged in tandem fashion, with the H.P. piston on top, the L.P. next, and the M.P. stage below (see plate facing p. 80, and p. 176). The pistons and extension trunks are of hollow cast iron, and are in two sections, the H.P. being a separate section and bolted to the L.P. and M.P. stages, which are in one piece. The castings are machined down to the dimensions required, grooves being cut on the surface of each piston to receive the Ramsbottom type packing rings. The compressor drive consists of a crank extension on the main shaft either at the forward or aft position of the main engines. For a description of the manufacture of the piston rings, see p. 577. The average dimensions and piston clearances run as follows :— L.P. compressor = 23 in. dia. I.P. ,, = 21 ,, H.P. ,, = 6 ,, L.P. clearance = $\frac{1}{10}$ inch I.P. ,, = $\frac{1}{4}$,, H.P. ,, = $\frac{7}{32}$,,

No.	QUESTION.	ANSWER.
476	Make a sketch showing the plates and joints of the principal seams of the boiler (cylindrical type).	Boiler furnaces and combustion chambers are fitted with single riveted lap joints. Boiler end plates and circumferential shell plates are fitted with double riveted lap joints. The longitudinal joints of boiler shell plates are fitted with double butt strap joints and special riveting (see p. 612). Strength of single riveted lap joints = 55 per cent. of solid plate. Strength of double riveted lap joints = 68 per cent. of solid plate. Strength of double butt strap joints = 85 per cent. of solid plate.
477	What fittings would you think necessary to prevent a deep tank filled with water from being pumped out by the bilge pump ?	A suction cock of the hollow plug single port type, which only permits water to be drawn from one connection at a time, would be suitable. Sometimes two flanges are fitted on the tank suction pipe, one being of the usual ring pattern and the other closed or solid, and when the latter is bolted up in position the tank will be tightly shut off against either suction from, or delivery to.
478	What difficulties are encountered in the case of slow running Bolinder engines.	The difficulties met with in running semi-Diesel engines at reduced load are cooling of the bulb, and therefore irregular firing, because of the fuel supply being less, while the air supply (unless a throttle is fitted in the scavenge port) is the same; therefore a poor firing mixture is being supplied and less heat is generated. The bulb is sometimes provided with a thin metal cover which can either be left in position (hot) or removed (colder) as required by the engine load. Exhaust gas temperature about 500° F. for full load. Exhaust gas temperature about 300° to 350° F. for light load. See p. 617 (No. 260).

No.	QUESTION.	ANSWER.
479	Write a letter to the shipowners describing defects which occurred to your cylinder heads, the repairs made, and any suggestions to prevent the same from occurring.	In this case the personal experience of the candidate should be utilised in drawing up an imaginary letter describing a defect and repair as specified.
480	Why does water circulation require more attention in the case of a 2-cycle engine than in a 4-cycle type ?	During a given period the 2-cycle engine requires to reject about double the quantity of heat of that for a 4-cycle engine ; therefore the quantity of cooling water and temperatures of piston cooling and cylinder cooling discharge water require regular and careful attention.
481	What might cause a cylinder liner to become overheated, what immediate precautions should be taken, and what might happen if these precautions were neglected ?	Want of cooling water, want of lubrication, or broken rings may cause a cylinder liner to overheat. If the heating is considered serious it may become advisable to cut out that particular cylinder altogether by shutting off the fuel, before serious damage ensues. A hot liner may result in fracture below the flange, breakage of piston rings, seized piston, and similar defects. (Also see question No. 559.)
482	How is a leaky air suction valve detected ? What might cause it, and what effect will it have ?	A leaky air suction valve will be indicated by hot sparks being ejected from the air suction inlet during the firing stroke. The leaky valve may be caused by a broken spring, cracking of the metal at the seat, or carbon deposits between valve and seat, etc.

No.	Question.	Answer.
483	State the merits and demerits of port scavenging, valve scavenging, and of supercharging.	Port scavenging does away with all cylinder cover scavenge valve openings and gear, and permits of large inlets for the incoming air. The disadvantages are that the piston lubricating oil is more easily lost by blowing through the ports, also that the guide bars between the port are apt to distort and crack due to temperature differences. Valve scavenging possesses no particular advantages, except that of better timing than obtained by plain ports uncontrolled by, say, a rotary valve (see p. 192). Supercharging admits of higher fuel consumption, more efficient combustion, and increased power output per cylinder or engine (see pp. 783-789).
'484	Detail the valve timings as usually arranged for, say, a Bolinder type (hot - bulb) engine.	Fuel injection starts 41° B.T.C. ,, ,, finishes 4° B.T.C. Exhaust port opens 65° B.B.C. ,, ,, closes 65° A.B.C. Scavenge air transfer port opens 45° B.B.C. Scavenge air transfer port closes 45° A.B.C.
485	Sketch a connecting rod for a semi-Diesel engine, and state the usual pressures employed. Also, is lubrication by forced or drip system, and why?	See pp. 468, 476. Compression pressure, 200 lbs. Explosion pressure, 300 lbs. Scavenge air pressure, 2½ to 4 lbs. The lubrication is of the forced feed system to main bearings and cylinder wall; by forced feed and centrifugal force (banjo ring) to bottom end; and by force feed and gravity to top end. The lubrication of a 2-cycle semi-Diesel engine requires careful attention when running, owing to the fact that the connecting rod is constantly under a compressive load, no relief or reversal of pressure taking place on either stroke, up or down.
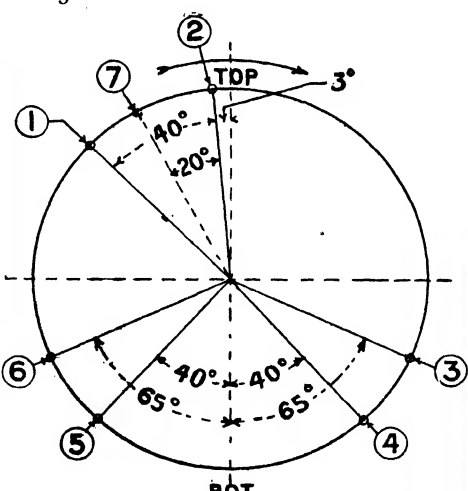
No.	QUESTION.	ANSWER.
486	Name the parts of a S.A. Diesel engine subject to wear down as compared to a steam engine.	In Diesel practice the maximum pressure only occurs on the downstroke, so that the crosshead bearings, bottom end bearings, and main bearings have the tendency to wear down more than in the case of steam engines. This tendency is corrected to a great extent by the general practice of employing forced lubrication.
487	Name all of the fittings of an auxiliary donkey boiler, and explain the use of each.	1. Safety valves to relieve the steam pressure. 2. Stop valve to control steam supply from boiler. 3. Feed check valve to admit feed water. 4. Surface blow-off valve to remove floating impurities. 5. Bottom blow-off valve to reduce the density. 6. Water gauge glass to test water level. 7. Steam pressure gauge to register the pressure carried. 8. Salinometer cock to test boiler density.
488	If an engine starts on air and then refuses to fire, what might be the cause?	1. Too low blast pressure. 2. Starting air slide has insufficient lift or is very leaky. 3. Starting air valves leaky or roller clearance excessive. 4. Pistons or air starting valves leaking badly. 5. Inlet or exhaust valves leaky. 6. Engine may be braked, either due to tight bearings or propeller fouled. 7. Water or air in fuel oil. 8. Leaky non-return valves in fuel oil pipe from pump to valve. NOTE.—If engine starts on air and rotates in the direction to the lead of the starting valve operated on, and then suddenly kicks back in the opposite direction, one or more of the other starting valves are leaky or sticking up.
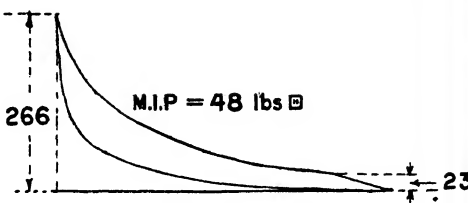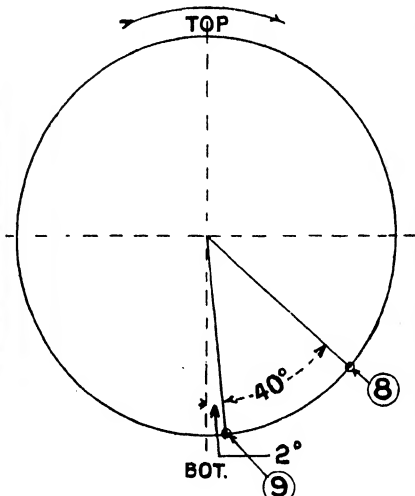
No.	QUESTION.	ANSWER.
489	Can a large Diesel engine be reversed from "Full Ahead" to "Full Astern" immediately, say, to avoid a collision?	Before the engine can be reversed from ahead to astern the starting handle requires to be brought back to the "stop" position, as otherwise the reversing wheel or handle is interlocked. When the starting handle is on the "air start" or "fuel" position, the reversing handle cannot be moved over.
490	Show by a worked out example how it is that less fuel is used per I.H.P. per hour in Diesel practice than with steam practice and oil fired boilers.	*Steam Practice.* Boiler efficiency = 75 per cent. Indicated thermal efficiency = 15 ,, Mechanical efficiency = 85 ,, Propeller efficiency = 65 ,, *Diesel Practice.* Indicated thermal efficiency = 42 per cent. Mechanical efficiency = 80 ,, Propeller efficiency = 65 ,, Assuming the heat value of the fuel oil to be 18500 B.T.U. per lb., Then, (steam) = $\dfrac{33000 \times 60}{18500 \times 778 \times \cdot15}$ = ·91 lb. per I.H.P. hour; and, (Diesel) = $\dfrac{33000 \times 60}{18500 \times 778 \times \cdot42}$ = ·32 per I.H.P. hour. NOTE. — "Brake Thermal Efficiency" ÷ Mechanical Efficiency = "Indicated Thermal Efficiency." It should be noted that in Diesel engine practice boiler losses are eliminated, with the result that the thermal efficiency is much higher. The mechanical efficiency, however, is lower, owing to the power required to drive the air compressors and scavenge pumps. From the foregoing it will be evident that the oil fuel consumption in Diesel engines per I.H.P. per hour is roughly about one-third that of steam engines with oil fired boilers.

No.	Question.	Answer.
491	Explain the meaning of "compression ratio," and give its average value. How is compression ratio affected by increased clearance volume?	"Compression ratio" refers to the volume of air contained in the cylinder at the beginning and end of the compression stroke, and on which depends the pressure and temperature produced. If the clearance volume is equal to, say, 8 per cent. of the stroke volume, **Then, Compression Ratio** $=\dfrac{100+8}{8}=13\cdot5$. The compression ratio ranges from about $12\cdot5$ to 14. If the clearance volume is increased the compression ratio will become reduced. In practice this might lead to difficulty in starting, also misfiring in running, owing to the temperature being too low for reliable ignition.
492	Explain electric, hot bulb, and compression ignition, and discuss the relative efficiencies. Mention the types of engines which use these different ignition systems.	In petrol and paraffin engines electric spark ignition is usually employed, as the compression pressure requires to be kept low owing to the low flash point of the fuel employed, the thermal efficiency being about 25 per cent. In hot-bulb engines ignition is obtained by the combined effects of low compression (200 lbs.) and the heat of the bulb. The thermal efficiency is about 30 per cent. In full Diesel engines ignition is obtained by the temperature of the compressed air (1100° F.) and the thermal efficiency averages about 33 per cent.
493	Why are Diesel engine cylinders less in diameter than steam cylinders?	Increase of cylinder diameter would require increase of cylinder liner thickness, with consequent difficulty of rapid and efficient heat transfer; it is therefore advisable to limit the diameter to, say, 30 in., as above this the severe heat stresses set up would result in distortion and danger of cracks.

No.	QUESTION.	ANSWER.
494	How can the working condition of the cylinder fuel valves of a solid injection engine be tested?	To ascertain if the various cylinder fuel valves of an engine are functioning properly, proceed as follows :— 1. If the cylinder valves are supplied by a single fuel pump arranged on the common "rail" system, shut off one cylinder fuel valve at a time and note the increase of fuel pressure on the fuel pump gauge; if an increase in the pressure difference occurs between any two cylinders, the faulty cylinder can be located. 2. Shut off one cylinder fuel valve at a time, and observe the colour of the exhaust gases at the funnel. If the colour becomes lighter when one particular cylinder is cut out, that cylinder valve may be assumed to be at fault.
495	A petrol engine operates on a constant volume cycle, and a Diesel engine on a combination of constant volume and constant pressure cycle. Explain fully the two cycles, and mention the merits and demerits of each.	*Constant Volume.* When combustion takes place under conditions of constant volume, the pressure rises quickly and throws a heavy initial load on the engine and shafting. Petrol, paraffin, and hot-bulb engines operate on this principle. When ignition takes place, the full pressure is reached before the piston has had time to move, hence the term "constant volume." *Constant Pressure.* When combustion takes place under conditions of constant pressure, the piston is moving outwards as ignition and burning takes place, so that the increase of volume balances what would otherwise be increase of pressure, with the result that the pressure remains constant; and the diagram shows the nearly flat top appearance associated with this cycle.

No.	QUESTION.	ANSWER.
495	— *Continued.*	In actual Diesel practice, however, combustion takes place under a combination of the two cycles described, and may be referred to as "dual combustion," being partly under constant volume and partly under constant pressure. The diagram, therefore, shows a slightly sloping line during the full opening period of the stroke. Combustion at constant pressure keeps down the initial load on the piston, and gives a fuller bodied diagram, which results in improved efficiency as compared with that of constant volume combustion. When, in Diesel practice, early firing occurs, combustion is taking place under approximately constant volume conditions.
496	Give your reasons for assuming that under full load and speed conditions combustion will be more complete in the case of 4-cycle blast air injection engines than with 4-cycle solid injection engines.	With blast air injection part of the air for combustion is obtained from the blast, whereas with the solid injection system volumetric efficiency has to be depended on entirely to supply the necessary amount of air, and therefore oxygen, required for combustion. Again, as the revolution speed increases, the volumetric efficiency falls off, so that with additional fuel supply the air supply is actually diminished instead of increased, which often results in a smoky exhaust. On the other hand, with blast air injection the blast pressure is increased with the load, and in this way the air supply is increased in proportion to the fuel supply. When the load is reduced the blast air pressure is also reduced.
497	Referring to a hot-bulb engine, state the average diameter and stroke of the fuel pump plunger.	The diameter of the fuel pump plunger for a 300 B.H.P. hot-bulb engine is 26 mm., or fully one inch, and the stroke ranges from 5 mm. to 7 mm. at normal load. At reduced loads the pump plunger stroke is reduced to about $1\frac{3}{4}$ mm., and less fuel is then injected into the cylinder. For engines of lower power the plunger diameter and stroke is less in proportion.

No.	QUESTION.	ANSWER.
498	Referring to the reversing charge of a hot-bulb engine, state the average crank angles for fuel injection opening and closing positions.	The reverse fuel pump is timed to inject the fuel charge at about 40° B.B.C., the fuel closing position being about 3° B.B.C. to 3° A.B.C., or at B.C. Explosion and combustion does not occur, however, until the piston has passed over the bottom centre and travelled about half-stroke up, at which position only the stroke clearance volume has been sufficiently reduced to permit of combustion taking place.
499	Referring to hot-bulb engines, state how the fuel supply is reduced when running at light loads.	The fuel supply is reduced by shortening the effective stroke of the fuel pump, by means of a hand control lever, or by governor action, the fuel timing then being somewhat as follows : fuel opens about 20° B.T.C., fuel closes 3° B.T.C. to 3° A.T.C.
500	Sketch out a normal ahead valve timing diagram for a hot-bulb engine.	

No. 481.—Valve Ahead Timing Diagram for Hot-bulb Engine.

1, Fuel injection opens (43° B.T.C. to 33° B.T.C.).

2, Fuel injection closes (3° B.T.C. or A.T.C.).

3, Exhaust ports open (65° B.B.C.).

4, Scavenge ,,   ,,   (40° B.B.C.).

5,   ,,   ,,   close (40° A.B.C.).

6, Exhaust   ,,   ,,   (65° A.B.C.).

7, Fuel injection opening for light loads (20° B.T.C. or later).

Note.—Fuel injection opening position ranges from about 40° B.T.C. to 15° B.T.C. in different builds of engines, and varies with the B.H.P., pressure, and temperature of compression obtained.

No.	Question.	Answer.
501	Sketch out, with pressures, an indicator diagram from a hot-bulb engine.	
502	Sketch out a reverse valve timing diagram for a hot-bulb engine.	

No. 482.

M.I.P = 48 lbs ▣

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No. 483.—Valve Reverse Timing Diagram for Hot-bulb Engine.

Note. — The exhaust and scavenge port timings are exactly the same as for ahead running. (See Question No. 500).

8, Fuel injection opening for reverse charge (40° B.B.C.).

9, Fuel injection closing for reverse charge (2° B.B.C., or at B.C.).

It should be noted that in ahead running fuel injection closing occurs at the same position for light loads or normal loads, the period of opening only varying in the two cases.

No.	QUESTION.	ANSWER.
503	Referring to hot-bulb engines arranged with the pre-ignition method of reversing, state the relative crank angles and firing order for a 4-cylinder engine.	The cranks of cylinders Nos. 1 and 2 are opposite to each other (180°), while the cranks of cylinders Nos. 3 and 4 are also opposite to each other and in line with the cranks of Nos. 1 and 2. The firing order is as follows : Nos. 1 and 3 fire together. and Nos. 2 and 4 fire together, thus making the angle of firing sequence 180°. This arrangement favours rapid reversal of the engine.
504	Describe how to place the fuel pumps at the exact bottom or "out" centre position, with the object of verifying the fly-wheel marking.	(1) Turn engine until the pump plungers are near the bottom or "out" stroke position, and mark the pump crosshead and guide. (2) With a compass or trammel fixed to a point on the pump crosshead guide, make a mark on the pump driving eccentric. (3) Turn engines until pump has passed over "out" centre position, and marks on guide and crosshead again coincide. (4) With trammel in same fixed position, again mark driving eccentric. (5) Finally, find exact centre between marks on eccentric, and turn engine until trammel or compass point comes in line with centre mark. The pump will then be at extreme end of the delivery stroke or exact bottom centre position, and the guide can be marked accordingly.
505	Describe, or show by sketches, the construction of a Cammell - Laird-Fullagar engine crankshaft.	See pp. 240, 747 ; Question No. 570.

No.	QUESTION.	ANSWER.
506	Referring to 4-cycle engine, describe the crank angles and firing order for a 4-cylinder engine.	In a 4-cycle, 4-cylinder engine all of the cranks are in line, with Nos. 1 and 4 cranks on top and Nos. 2 and 3 cranks on bottom, that is, opposite, or at 180°. The firing order requires to be as follows : 1, 2, 4, 3, as this distributes the two impulse strokes per revolution evenly.
507	Sketch out or describe the reversing gear for a Bolinder type hot-bulb engine.	See p. 479, and plate facing p. 480.
508	State how far on the stroke the fuel is injected in a hot-bulb semi-Diesel engine.	See question No. 500, p. 723. *Note.*—It should be observed that fuel is injected during the *compression stroke*, and not on the working or impulse stroke.
509	Enumerate the various types of boilers employed in modern marine practice and mention the pressure carried in each.	The boilers in general marine use are cylindrical (220 lbs.), Yarrow water-tube, and Babcock water-tube (up to 550 lbs.). For auxiliary purposes Cochrane and Clarkson type waste heat boilers (100 lbs.) are usually fitted in Diesel engined vessels. See pp. 544, 548, 657, 658, and plates facing p. 1054.
510	Describe or sketch out the method of reversing employed in Werkspoor single-acting engines.	See pp. 132, 266, and plate facing p. 140.
511	Referring to the boiler water-gauge column, describe all you may happen to know concerning same. What different causes may give a false reading in the glass ?	See p. 848.

No.	QUESTION.	ANSWER.
512	Mention the principal fittings for an oil fuel fired boiler system. Also what precautions require to be taken in the handling of the fuel, and in the working of the same ?	See plate facing p. 1054 ; also see Questions Nos. 380, 381, 382, 403.
513	Assume that one of the crank lengths has been under repair, and when returned it is found that the crank angle is wrongly set. If time will not permit of further alteration describe how the engine should be run to compensate for the error in the crank angle.	If the crank angle is in advance of the true position, it would be advisable to advance the timing of the fuel valve of that engine, and, similarly, if the crank is behind the correct position the fuel valve timing should be correspondingly retarded to reduce risk of excessive shock stresses on the shaft material.
514	Describe or sketch out an electric motor starting switch, and explain how it should be manipulated when starting up and when stopping a motor.	See plate facing p. 989.
515	Give a diagrammatic sketch of the cylinder liner and valves of a double-acting Diesel engine.	See plate facing 102, and pp. 128, 800, 801, 810.
516	Sketch a boiler single-riveted lap joint with dimensions, and mention three ways in which the joint may give out.	See p. 849.

No.	QUESTION.	ANSWER.
517	What are the preventions employed against overheating of dynamos ? If overheating takes place what effect has this on the load ?	To prevent overheating of the armature conductors, air spaces are usually provided in the boss on which the coils are wound. Heating of the armature or magnet coils would result in additional load being thrown on the machine, as the conductivity of copper falls off with increase of temperature, so that fusing of the conductors might take place. For sudden rise of temperature in external conductors, fuses are fitted, those being composed of lead or tin, or of tinned copper, with a low temperature melting point. The fuses act as automatic circuit breakers and prevent damage to the main wiring. Tinned copper is suitable for fuse wire. It may be stated that all electrical generators when running at full load tend to develop a rise of temperature in the conductors for the reason that work is being done by current flow. As mentioned previously, the effect of this is to increase the load on the machine.
518	Explain how to determine the E.H.P. of an electric motor from the instruments fitted on the switchboard. Also find the approximate fuel consumption per twenty-four hours assuming a Diesel engine drive.	Assume, Volts = 110. Amperes = 600, then, $\text{E.H.P.} = \dfrac{110 \times 600}{746} = 88 \cdot 4.$ Allow a combined mech. efficiency of, say, 75 per cent. Then, B.H.P. $= 88 \cdot 4 \div \cdot 75 = 118$ nearly. For Diesel auxiliary engines allow a fuel consumption of, say, $\cdot 5$ lb. per B.H.P. hour. Then, Consumption $= \dfrac{118 \times \cdot 5 \times 24}{2240} = \cdot 63$ ton per 24 hours.
519	State which is the most effective method of clearing out oil vapour from double bottom tanks.	Steam is the most effective means of getting rid of gas present in pumped-out oil tanks and for tanks of, say, 1000 tons capacity the steaming out process may require a period of about ten hours. After steaming out, a chemical test is taken of the gases remaining in the tank, and if found satisfactory a certificate to that effect should be given by the chemist conducting the test. Also see p. 892.

No.	QUESTION.	ANSWER.
520	How often during each revolution does firing take place in (a) a 4-cylinder, 2-cycle engine, and (b) a 4-cylinder, 4-cycle engine? Also state order of firing for each.	In a 2-cycle engine with four cylinders firing takes place at intervals of 90°, that is, four times per revolution. In a 4-cycle engine with four cylinders, firing takes place at intervals of 180°, or twice per revolution. Order of firing—2-cycle: 1, 4, 2, 3. 4-cycle: 1, 2, 4, 3.
521	Describe some recent methods employed for the utilisation of exhaust gases.	Exhaust gases may be utilised as follows :— 1. To generate steam in low pressure waste heat boilers. 2. To provide heating of water for baths and other domestic purposes. 3. To operate an exhaust gas turbine for supercharge purposes. See pp. 812-815, 783-790.
522	Explain what effect the crankshaft torque may have on the valve timing of the engine cylinders.	Assuming that the camshaft drive is placed midway in the space occupied fore and aft by the cylinders, the twist on the shaft would cause later timing of the valves at the forward cylinder section, and to correct which the fuel valves of these cylinders should be slightly advanced when setting same.
523	State what angle to each other the ahead and astern fuel valve cams should occupy in the case of (a) a 2-cycle engine, and (b) a 4-cycle engine for the following valve timing :— Fuel valve opens 5° before top centre, and closes 40° after top centre.	**2-Cycle Engine.** $40° + 5° = 45°$ **open to fuel,** and $45° \div 2 = 22\cdot5°$. So that $22\cdot5° - 5° = 17\cdot5°$ **from centre of engine to centre of cam.** Distance between ahead and astern cam **centres** $= 17\cdot5° \times 2 = 35°$. **4-Cycle Engine.** Camshaft travel $=$ half travel of main shaft. So that $90°$ **on camshaft** $= 180°$ **on main shaft.** Then, $35° \div 2 = 17\cdot5°$ **between ahead and astern cams.** Also see plate facing p. 356.

No.	QUESTION.	ANSWER.
524	How should the knife edge of the oil scraper ring be placed in the case of main engines and trunk type auxiliary engines, and why ?	In main engines the scraper rings are fitted with the object of preventing the escape of lubricating oil downwards, therefore the knife edge should be placed pointing upwards. In trunk type auxiliary engines the object is to prevent the admission of lubricating oil into the cylinders, therefore the knife edge of the scraper ring should be placed pointing downwards.
525	If in stopping, with fuel shut off, the engines continue still turning for an appreciable period, would it be advisable to shut off the blast air, and why ?	When stopping (in cases when the fuel valve is still in operation) it is advisable to leave on the blast air with the object of preventing the hot compressed suction air being blown back into the blast air pipe line with danger of explosion.
526	If in stopping the engines continue turning after fuel is shut off, and, after the gear is reversed and astern starting air is turned on, the engine still continues running ahead, what will be the effect of this on the starting air supply ?	If the astern air-starting cams were in action while the engines are still running ahead, the main pistons would then be acting as air compressors, and the starting air would be forced back through the starting air valves. The starting air valves would open at, say, 120° from the bottom centre and close 10° or 15° from top centre owing to the fact that the camshaft would be revolving in the opposite direction to that intended. In the case described it is likely that the cylinder relief valves would lift as the pistons came up to top centre position.
527	As it is necessary in reversing that the engines should be brought to a dead stop before turning on starting air, what means of ensuring this might be adopted ?	In certain builds of engines electric or hydraulic brakes were fitted to the flywheel with the object of bringing the engines quickly to rest when the fuel is shut off, the brake pressure being afterwards automatically released, but this practice is now discontinued. See Question No. 556.

No.	QUESTION.	ANSWER.
528	Assuming that the revolutions are 80 and the B.H.P. 2600, show how to calculate approximately the B.H.P. when the revolutions are increased to, say, 114.	If the slip per cent. were to remain constant the revolution speed would be an exact measure of the ship speed, and as the B.H.P. is a measure of the fuel consumption, then the power would vary as the revolutions cubed:— So that As $80^3 : 114^3 :: 2600 : 7527$ B.H.P. Ans.
529	Give a brief description of the hydraulic transmission geared down system as applied in Diesel engine practice.	See Question No. 546 ; also pp. 737-739.
530	Mention the principal stresses to which Diesel engine crankshafting is subject to.

What is the general rule for obtaining what is called the " equivalent twisting moment " of a shaft ? | The crankshafting of Diesel engines is subject to combined bending moments and twisting moments, together with shearing forces which act near the position of the main bearings. The maximum stresses set up are due to bending moments owing to the heavy initial loads on the pistons. Rankine's rule for equivalent T.M. allows for combined twisting and bending moments, and is expressed as follows :—
$$T_1 = M + \sqrt{M^2 + T^2},$$
where T_1 = Equivalent twisting moment. „ T = Twisting moment. „ M = Bending moment.

The moments referred to act to produce compressive, tensile, torque, and shear stresses on the shaft material. Also see p. 819. |
| 531 | Referring to built type Diesel crankshafting, give the allowance for shrinkage usually adopted, also the proportions for " securing " pins. | A good allowance for the shrinking in of crank webs to shaft bodies and to crankpins is $1\frac{3}{4}$ thousandths of an inch per inch diameter of shaft. For " dowal " or securing pins the diameter is often equal to about $\frac{1}{8}$ of shaft or pin diameter, the length of the pins being made equal to ·8 of the web thickness. |

No.	Question.	Answer.
531	—*Continued.*	The pins are usually made a driving fit and have a slight taper, say $\frac{1}{16}$ in. in the length. It is also advisable that the two securing pins be not placed at the vertical centre line of the web but to one side, with the object of maintaining the strength of the web at its weakest section.
532	Assuming that a 4-cycle engine could be run astern on the ahead cam, describe the sequence of events due to reversed valve timings.	If a 4-cycle engine were rotated astern without reversing the cams, the valve timings would occur as follows :— The fuel valve would open at about 40° B.T.C., giving a heavy pre-ignition firing effect; the air suction valve would open next and discharge the gases of combustion into the engine-room, after which the exhaust valve would open and allow the admission of gases from the exhaust box; and finally, when the exhaust valve closed, compression would begin.
533	Referring to crank-shafting, mention the average position of the crank at which the combined bending and twisting moments attain a maximum value. Under what condition may the bending moments become dangerously excessive ?	When the crank position is about 30° A.T.C., the combined bending and torsional stresses are at a maximum, the torsional stresses reversing in direction at the end of the compression stroke and the beginning of the firing stroke. The maximum bending moments also take place at the end of the compression stroke and at firing position, those moments setting up compression and tensile stresses on the shaft material, the tension being most severe on the shaft structure. In starting up from cold the bending moments are excessive, as the inertia of the working parts requires to be overcome. Misalignment of the shafting tends to intensify the stresses referred to, and may lead to serious shaft fracture. Dangerous initial loads may also be generated through a leaky fuel valve which might give rise to an overcharge of fuel.

No.	Question.	Answer.
533	—*Continued.*	Over-priming of the fuel valve previous to starting up would give similar results. It should be noted that exceptions to the foregoing occur in the case of opposed piston engines, such as the Doxford and Cammell-Laird-Fullagar, in which the bending moments are neutralised, with the result that the main bearings are relieved of pressures due to firing impulses, torsional stresses only requiring to be transmitted. See p. 900.
534	Assume that previous to starting up it is suspected that the fuel valves have been overcharged by means of the hand priming pump. Explain how you would work the engines to get rid of the surplus fuel which otherwise ·might lead to dangerous firing loads.	If the cylinder fuel valves have been over-primed, a quantity of oil might be accumulated on the top of the pistons, which if ignited might lead to excessive firing pressures ; it would therefore be advisable to run the engine on air only for a certain number of revolutions, say from three to four. The oil would in this manner be dissipated.
535	If marks resembling flaws are noticed on the shaft or crank pins, describe how to test if these may be considered as serious.	Carefully clean and dry the metal surface at the position of the marks, afterwards tapping with a light smooth-nosed hammer, and if oil exudes,' the shaft may be considered as defective.*
536	Describe how to test if a crank web is loose on the shaft.	Place the suspected crank web in a horizontal position, and carefully clean and dry the metal at the position of the dowel pins : next, turn the engine over until the web is at the opposite horizontal position, and if oil exudes from either the bore of the web or from the dowel pin holes, the web may be considered as being slack on the shaft, the shrinkage having failed. In the two ·positions described, the weight of the web, if loose, will be supported on each side of the dowels alternately, and the oil will be squeezed out by pressure.

* The location of a flaw can also be detected by the following method :—

1. Carefully wipe dry the suspected shaft surface and sprinkle same with powdered chalk.

2. Blow off the powdered chalk and a clear raised line will then remain indicating the exact location of the flaw.

No.	QUESTION.	ANSWER.
537	Referring to failures of crankshafting, describe how this may be caused.	In the case of a six or eight cylinder engine, it is quite possible that the main bearings of, say, cylinders No. 2 and No. 4 may not be worn down as far as the main bearings of No. 3, and if this is the case the main bearings of cylinders No. 2 and No. 4 will be supporting the shaft of cylinder No. 3 in the form of a beam supported at either end. When, therefore, the engines are running the shaft of No. 3 will be pounded into the bearing, and a severe bending stress will be exerted on the material, which stress may ultimately bring about complete fracture of the shaft. Bridge gauge readings, therefore, cannot always be relied upon, and to verify the wear down it may be necessary to coat the shaft with red lead and turn the engines round, afterwards examining for contact marks on the red lead surface.
538	Compare the torsional stresses transmitted by the crankshafting of a 4-cycle, 4-cylinder Diesel engine with that of a 4-cylinder steam engine.	In the case of a 4-cylinder steam engine, the torsional stresses transmitted along the crankshafting are cumulative in nature, that is, the after length of No. 2 cylinder shaft transmits double the torque of No. 1, that of No. 3 three times the torque, and that of No. 4 four times the torque of No. 1, assuming equal power development in each cylinder. In a 4-cycle, 4-cylinder Diesel engine, the power transmitted along the crankshafting is less proportionally, as when, say, cylinder No. 1 is firing, cylinder No. 2 is on the air compression stroke, and is therefore transmitting no power to No. 3, which thus only receives the power of No. 1. In the same manner, when No. 2 is firing, No. 3 is on the air suction stroke, and the power transmitted to cylinder No. 4 will be that of No. 2 cylinder only.

No.	Question.	Answer.
539	Describe and sketch out the cylinder head of an internal combustion engine other than Diesel. Show how the head is secured to the cylinder.	The head of a hot-bulb engine is usually fitted to the cylinder by means of a grooved joint, and is held in place by a separate retaining ring. The head is ground into position, and the retaining ring fitted over the head, the whole being secured by suitable studs, which, when tightened up, form a gas-tight joint. In some cases, the half-spherical hot bulb portion of the head is formed separately, and clamped in position by the retaining ring (see p. 464). This arrangement allows of removal and replacement of the heated bulb in case of fracture by overheating. The fuel injector is fitted into the head so that the jet is directed against the heated portion of the bulb. In some cases a cooling water jacket is fitted round a portion of the head, and, in addition, a portable hood which can be left in position over the bulb when running at low loads to maintain a high temperature, and removed when running at heavy loads to reduce the temperature.
540	Give a list of causes for false indications in a boiler water-gauge glass. Also describe how to fill up a boiler and get up steam.	See p. 848. False readings may be caused as follows :— 1. Choked or closed cocks. 2. Gauge glass too long and covering the small hole in the plug of the cock. 3. Pipes from column to boiler choked. 4. Packing of the glass overlapping the ends of the tube and closing up the opening. 5. Leaky drain cock. 6. Handle of cock twisted, and therefore misleading when in, say, "open" position. Before filling a boiler it is advisable to enter and see that no waste, oil, etc., has been left behind by the cleaners; also examine top and bottom gauge cock connections internally, and see if

No.	QUESTION.	ANSWER.
540	—*Continued.*	scum pan is in correct position. Then put on bottom doors and pump up the boiler until, say, 3 in. water appears in the glass. If possible, the actual water level and the recorded level should be checked. Fit on top main manhole door carefully, after which open the top cock of the water gauge and start away the fires easily, and circulate the water meantime. At intervals, go round and harden up the doors as heat is generated and expansion takes place. When steam blows out of the gauge cock close same, and verify the gauge glass indications.
541	What is meant by the term " thermal efficiency " ?	By thermal efficiency is meant the ratio of heat energy or work given out by an engine compared to that put in. " Brake " thermal efficiency averages about 34 per cent., and " indicated " thermal efficiency about 44 per cent., with a mechanical efficiency of, say, 78 per cent., as, $34 \div \cdot 78 = 44$ per cent. nearly.
542	What is the average fuel consumption per B.H.P. for main engines, and how is it affected by increase of revolution speed ? How does the fuel consumption vary in the case of auxiliary engines driving electrical generators and running at constant revolutions ?	About ·41 lb. per B.H.P. hour. With main engines increase of revolution speed is equivalent to increase of load or power, racing excepted, so that the fuel consumption per B.H.P. will decrease. In the case of auxiliary engines driving generators at constant revolutions, the fuel consumption per B.H.P. hour will (as before) decrease with increase of load or power. *Note.*—It should be noted that the fuel consumption per I.H.P. (*not* B.H.P.) hour is *least* at low loads or powers, and *most* at high loads or powers.
543	Explain how the efficiency of air compressors is affected by the following :—	(*a*) If the clearance volume be excessive, the number of compressions would be reduced and the efficiency lowered, as the final compression pressure would be less than that required.

No.	QUESTION.	ANSWER.
543	*—Continued.* (*a*) Excessive clearance volume. (*b*) Insufficient cooling water supply. (*c*) Restricted L.P. suction air admission.	(*b*) An insufficient supply of cooling water would result in the final temperature of the air being high and the volume large, giving reduced efficiency; also by the presence of moisture in the air, which would otherwise deposit in the coolers. (*c*) If the air supply to the L.P. compressor suction valve is throttled, the machine would now be producing a reduced quantity of air, and, under these conditions, being of larger capacity than required for the work done, would fall off in efficiency.
544	Describe or sketch out the " director " valve of a Beardmore-Tosi 4-cycle engine, and explain its operation.	
545	Describe or sketch out a system of valve-controlled scavenge ports for a 2-cycle engine.	
546	Describe the hydraulic transmission gear as employed in Diesel engine practice, and mention some of the advantages claimed for this system.	In the Beardmore-Vulcan type of hydraulic coupling (see No. 484a) two driving engines are coupled to a single propeller shaft by means of pinions and a gear wheel, the engines both running in the same direction of rotation. Single reduction helical gearing is employed, and the main engine shaft is coupled to a rotor, the companion half of the rotor being secured to the pinion flange, contained within the casing, each being provided with suitable radial vanes. The pinions gear with the large wheel secured to the propeller shaft, the gear-down ratio being 2·88 to 1, or

No.	Question.	Answer.
546	—*Continued.*	equivalent to 240 engine shaft revolutions to about 80 propeller shaft revolutions. The fluid employed in the coupling is lubricating oil at a pressure of about 50 lbs., this being pumped into the coupling casing by special pumps. *Action.*—With the main engines running and the required oil pressure in the coupling, the driving member (attached to the shaft) discharges the oil by centrifugal force from the radial blades against the companion blades of the driven member attached to the pinion, the latter revolving and giving motion to the gear wheel of the propeller shaft, the slip between the two being not more than 3 per cent. If the drain valves are opened the casing is rapidly emptied, and when the oil pressure falls off the pinions cease to revolve, with the main engines still running light under governor control. Reversing is effected by stopping and reversing the main engines, after which the coupling case is rapidly filled with oil and the gear at once commences to function and drive the propeller shaft. The rotor acts, within limits, as a flywheel, and in addition it may be mentioned that ahead axial propeller thrust is partly balanced by the oil pressure acting on the driven member of the fluid coupling. A small single collar Michell thrust is, however, also provided on the pinion shaft to absorb any out of balance thrust which may develop under different conditions of running, or when starting and stopping, or in astern running. The pinions are bored out hollow, and an extension shaft passes through to drive by gearing the oil filling and emptying pumps placed aft. As

No.	QUESTION.	ANSWER.
546	—*Continued.*	mentioned previously, the fluid employed in the coupling is lubricating oil, this being contained in an overhead tank, to which the oil is pumped up by the special pumps referred to from the sump in the casing of the coupling. Emptying and filling of the casing is controlled from the starting platform by a ring valve arranged on the circumference of the rotor, which opens or closes ports on the rotor periphery, the gear for operating same being carried through the hollow extension of the shaft (see sketch). A piston valve is also provided which opens or closes the connection to the overhead oil supply tank. The elastic nature of the fluid coupling, as described, acts to damp out the torsional vibrations due to the weight of reciprocating parts and to the firing impulses, and gives a smooth propeller shaft drive (see plate facing p. 738).
547	If the wear of the fuel valve cam became excessive, state what might happen ?	If the wear of the fuel valve cam exceeds in amount the lift of the valve, no valve lift would take place, and the repeated deliveries of fuel from the fuel pumps would finally result in building up of high pressure in the fuel pipe and fracture of the same.
548	Assuming the fuel opening period to be equal to, say, 40° of the crank circle state, which of the two following valve timings is to be preferred, and the reasons ? A, Fuel opens 5° B.T.C. and closes 35° A.T.C. B, Fuel opens 15° B.T.C. and closes 25° A.T.C.	The valve timing (A) is to be preferred for the reason that in valve timing (B) the early opening of 15° B.T.C. might lead to the generation of heavy initial piston loads, as combustion would then be taking place under conditions approximating to constant volume.

No.	QUESTION.	ANSWER.
549	If the exhaust gas temperature of one cylinder is found to be in excess of that of the other cylinders, mention the different causes which may produce this effect.	If the pyrometer temperature reading of one cylinder of an engine is higher than that of the other cylinders, the cause may be as follows :— 1. Overloading, due to excessive fuel supply. 2. Leaky exhaust valve, allowing high temperature gases to pass back. 3. Early opening of exhaust. 4. After burning. 5. Difference in lift of fuel valve, admitting less blast air to one of the cylinders and giving, in consequence, a higher exhaust gas temperature. In cases 2, 3, 4, and 5, the power output of the cylinder affected would be *below* normal and not above normal, as might perhaps be assumed by the increase in temperature registered.
550	Describe a method of removing deposits of hard scale from water jacket spaces.	Deposits of scale can be removed from the internal surface of water jacket spaces by filling up with a four to one solution of water and hydrochloric acid or Clensel, the solution to remain for, say, three or four hours before removal, after which thorough cleaning out with clean water is essential.
551	Mention the deposits which form on the intercooler coils of air compressors, and how these can be removed.	As sea-water circulation is employed in the intercoolers, scale deposits may form on the outside surfaces of the coils due to the high temperatures of the air. Lubricating oil, if used to excess, may be present in the air, and carbon deposits form on the inner surfaces of the coils, the cause as before being due to heat. The coils require to be removed and the scale cleaned off, and to get rid of the carbon deposits on the internal surfaces the coil may be heated to a dull red and low pressure steam blown through from end to end. It should, however, be mentioned that this method of cleaning requires very great care indeed, as it is a very easy matter to burn the tubes through when heating up.
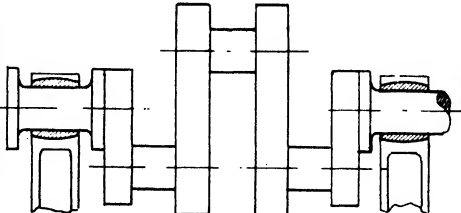
No.	QUESTION.	ANSWER.
552	What are the starting air valve timings for a four-cylinder Doxford engine ?	The starting air cams are provided with two peaks, the first admitting air 8° A.T.C. and closing 75° A.T.C., and the second, which is intended to be employed in cases of emergency, is larger than the first, the timings being : valve opens 5° A.T.C. and valve closes 95° or 100° A.T.C., but in ordinary practice the first peak only requires to be brought into operation when starting on air. The lift of the air starting valve averages fully ½ in.
553	Referring to Harland & Wolff 4-cycle engines, describe how starting air can be admitted to three cylinders out of six cylinders, the other three being on fuel.	To permit of the distribution of the starting air supply mentioned, twin air slides are required, as with a single air slide the cylinders are either all on air or all on fuel. Also see pp. 66, 805-807.
554	State the fuel valve timings of a Doxford engine, also the firing sequence of a four-cylinder engine.	Fuel valve opens 25° B.T.C. and closes 25° A.T.C. In the new four-cylinder high power engines the ahead firing sequence is as follows, 1, 4, 2, 3, and for astern, 1, 3, 2, 4. The cranks of cylinders 1 and 2 are opposite to each other (180°), and the cranks of cylinders 3 and 4 are also opposite to each other (180°) but are at 90° to the cranks of cylinders 1 and 2.
555	State the causes of explosions in starting air pipe lines.	An explosion in the starting air pipe line may be caused by a leaky valve allowing oil to get into the pipe, or, if no joint is fitted round the neck of the valve at the cover top, oil from a leaky fuel valve gland might leak down inside the pocket, thence to the pipe. Whenever starting air is turned on a violent explosion would take place.
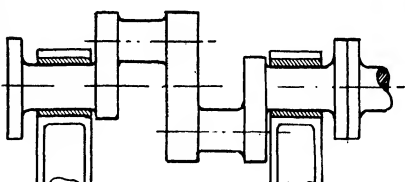
No.	QUESTION.	ANSWER.
555	—*Continued.*	Excessive lubrication of compressors may also be the cause of explosions in starting air lines, or leakage of lubricating oil along the crosshead pin of the compressor drive, the oil ultimately finding its way into the cylinder. The presence of oil gas in tne starting air line can be tested for by opening the drains fitted on the pipes when the starting air pressure is off.
556	Describe a method of " braking " an engine after fuel is shut off and the shaft is still revolving due to the inertia of the vessel. .	In the " Doxford " system a special decompression valve or air brake, operated by starting air, is fitted at the centre of the cylinders. The valve is cam operated and by pulling 'a small hand lever the cam is brought into mechanical operation and acts to open the decompression valve exactly when the two pistons are at the " in " or compression position of the stroke. The compressed air is thus released and passes through a valve into the adjacent cylinder, the valve then closing. The pistons now acting against a vacuum pull in place of being assisted by air expansion, are caused to bring up by means of the increased resistance developed, while the pistons of the other cylinders are held apart by the increased pressure resistance obtained from the air admitted as described.
557	Referring to fuel oils, explain the meaning of the terms "gross calorific value" and " net calorific value."	During combustion the hydrogen content of the fuel combines chemically with atmospheric oxygen to form water vapour in the ratio of 1 lb. hydrogen and 8 lbs. oxygen to give 9 lbs. steam, and as at atmospheric pressure the latent heat value of the steam is equal to 966 B.T.U. per lb. Then, $966 \times 9 = 8694$, or, say, 8700 B.T.U.'s in all.

No.	QUESTION.	ANSWER.
557	*—Continued.*	Each per cent. hydrogen content will therefore be equal to $8700 \div 100 = 87$ B.T.U.'s wasted in forming water vapour. The heat lost in this way is thus equal to per cent. hydrogen $\times 87$. *Example.*—The gross calorific value of a fuel, as determined by Bomb calorimeter test, is equal to 18600 B.T.U.'s per lb., and the hydrogen content $= 12$ per cent. Then, net calorific value $= 18600 - (12 \times 87) = 17556$ B.T.U.'s per lb. For the accurate calculation of thermal efficiency and fuel consumption per B.H.P. hour the net calorific value of the fuel requires to be taken, as for a given fuel consumption the thermal efficiency will be increased if the net calorific value be taken in place of the gross calorific value.
558	In taking a turn of the engines previous to starting, mention any particular position at which the engine should be placed to ensure prompt starting up.	After taking a preliminary turn it is advisable to place the engines in such a position that the fuel pumps will be on bottom stroke, otherwise the hand fuel pumps may fail to charge up the pipe line owing to the pump suction valve being held off its seat by the tappet rod.
'559	In the case of, say, a very hot piston rod or a hot cylinder liner, what means would you adopt to lower the temperature without stopping the engines?	The application of a mixture of lubricating oil and white lead will act to draw out the heat and bring back the temperature. For one gallon of oil add between three or four tablespoons of white lead, and the mixture may be applied by swabbing or by hand pumps or syringe.
560	Give the composition of a good white metal suitable for top end, bottom end, and main bearings. How are oil gutters arranged?	For heavy bearing pressures, white metal of the following composition will give satisfactory results :— Tin $= 78$ per cent. Antimony $= 12$,, Copper $= 6$,, Lead $= 4$,, $\overline{100}$

No.	QUESTION.	ANSWER.
560	—*Continued.*	For efficient lubrication the white metal-bearing surfaces in the lower half of main bearings are usually provided with two longitudinal oil gutters and two circumferential oil gutters, the edges of the gutters being washed away to promote flow of the lubricant. The oil inlet hole is usually bored in the lower half main bearing, but in some cases the oil hole is placed in the upper half of the bottom end bearing.
561	Describe how the cylinder fuel valves of a Doxford engine are primed up previous to starting from cold.	In Doxford engines the cylinder fuel valves are primed up by means of the auxiliary steam fuel pump, which latter is set away some time previous to starting up the main engines. Owing to the high fuel pressure employed (about 6000 lbs. per sq. in.) hand priming becomes impracticable.
562	Referring to Doxford engines, explain how the cylinder fuel valves function when running ahead and running astern.	When running ahead, two fuel valves are in operation, but in astern running the front fuel valve functions only, the back valve becoming inoperative as a single cam only is provided on the actuating arm of the valve gear. The front fuel valve is provided with two cams, one for ahead and one for astern operation, and functions in either direction of running as required.
563	In the case of a Doxford engine fuel valve, describe how the needle valve is caused to open.	The valve spindle is in three separate sections, and one portion only is moved outwardly by the cam actuating gear; when this occurs the difference of pressure due to difference of area of the needle valve spindle produces motion or lift, and the fuel is then injected through the small openings of the valve sprayer. The outer portion of the spindle merely regulates the amount of lift. See p. 208.

No.	QUESTION.	ANSWER.
564	Referring to cylinder fuel injection, describe a "spill" valve and how it functions.	In certain builds of engines, such as the "Still" and "M.A.N." types, a "spill" valve is fitted on the fuel valve chest at the discharge position. The spill valve may be described as a type of by-pass valve which acts to suddenly reduce the pump delivery pressure by opening a connection to the suction side when the period of fuel admission has been completed. The fuel valve cam regulates the timing and the spill valve the duration of fuel injection period. The spill valve is operated by the fuel valve lever and is under both governor and hand control. The function of the spill valve is to break the high pressure of fuel pump discharge suddenly at the end of the fuel delivery period and return the surplus or spilled oil back to the suction side of the pump. The sudden drop in fuel pressure reduces the tendency for drops to form in the fuel valve nose, and eliminates the building up of high pressures in the fuel valve piping when the fuel valve is in the closed position, and therefore discounts considerably the effects of a leaky fuel valve. As stated previously, the fuel valve opening timing remains constant, but the period of fuel injection for any load is controlled by the action of the spill valve. The spill valve acts to take the place of the usual suction valve tappet in controlling the delivery period of the fuel pump stroke, a hand suction valve lifter only being fitted. See pp. 831, 906-909.
565	Referring to air compressors, explain why, when working under reduced output, the H.P. compressor stage may tend to become overheated.	When the compressor output is reduced by throttling the L.P. suction inlets, or by blowing off air, the suction pressures will be reduced at each stage, although the delivery pressures may remain as before.

No.	QUESTION.	ANSWER.
565	—*Continued*.	If, then, the L.P. suction air pressure is reduced, the compression ratio will be proportionally increased, with the result that, being approximate adiabatic compression, the temperature will be considerably higher for the same delivery pressure as formerly. (See p. 827.) This may lead to carbonisation of the lubricating oil and damage to the delivery valves and springs.
566	Describe the cam adjustment required to alter the fuel valve timing from " opens 5° B.T.C. and closes 40° A.T.C. " to " opens 7° B.T.C., closes 40° A.T.C."	To give earlier opening and the same closing as before, the cam toepiece will require to be advanced half the amount, that is, one degree, and a liner inserted under the toepiece equal to one degree difference in timing. This adjustment will cause the valve to open earlier but to close at the same crank angle as previously.
567	The fuel valve opens 6° B.T.C. and closes 35° A.T.C. : describe the adjustments required to change the timing to " valve opens 6° B.T.C. and closes 40° A.T.C."	The cam will require to be put back half the amount, that is $2\frac{1}{2}°$, and a liner inserted under the toepiece an amount equal to give $2\frac{1}{2}°$ difference in timing.
568	Describe how to correct the fuel valve setting if the cam is found to be badly worn.	The cam toepiece will require to be advanced half the amount required, and a liner inserted under the toe, also equal to half the amount required.
569	Sketch and describe the crankshaft of a " Junkers " type Diesel engine. Compare the stresses on an intermediate crankshaft journal with those on the corresponding journal of a steam engine.	

No.	Question.	Answer.
569	—*Continued.*	A Doxford engine is a type of modified "Junkers" engine (see plate facing p. 10), and the stresses on the journals due to firing loads are practically nil, as at all positions the upward forces are balanced by the downward forces, the bearings only carrying the weight of the shafting and gear, bending moments being thus eliminated. The twisting moments and torque stresses applied to the shafting are more severe in nature than those in steam engine shafting owing to the increased piston loads due to firing and to the angle of the cranks which are opposed (180°), but this depends chiefly on the number of cylinders fitted, and diminishes with increase in number. Referring to the sketch, it will be noticed that the shaft lengths are coupled and bolted to the crank webs, also that the bearing shells are of spherical construction.
570	Sketch and describe the crankshaft of a Cammell - Laird-Fullagar engine, and compare the stresses to those on a steam engine crankshaft.	See answer to previous question (No. 569).
571	Describe summer tanks. Where are they placed and how are they used?	Summer tanks are usually fitted in oil-carrying vessels, and are placed on the port and starboard sides at about the level of the main deck. These tanks are only intended for use under good weather conditions, and are arranged to form expansion trunk extensions for the main hold oil cargo spaces. The fittings include a pumping up valve and pipe, air-vent pipe, sounding pipe, and a drain valve operated

No.	Question.	Answer.
571	—*Continued.*	by an extension spindle and wheel at the top of the tank. The drain valve allows the contents of the summer tank to drain off into the main hold tank below. One summer tank is usually provided to each pair of hold tank divisions. In place of the vent pipe mentioned, sometimes a removable screw cap is fitted on the top of the summer tanks.
572	What precautions are taken in bunkers with regard to fire ? Where should inflammable oil paints be stored, and what precautions taken regarding same ?	See Question 380, also p. 767. No naked lights should be allowed near bunkers, and all electric wiring requires to be of armoured cable, with the lamps enclosed in wire netting. Oil paints require to be contained in airtight drums, and stored in a place away from heat, such as the fore part of the ship. Bottles of CO_2 gas should be kept handy, also boxes of sand, in case of outbreak of fire.
573	Describe any type electrical pyrometer. How is the electrical current produced, and how is it arranged to register on the instrument ?	See pp. 367, 538, 681.
574	Discuss the pressure on the guides of steam engines and on single - acting Diesel engines. Extra marks will be allowed for a sketch showing the resultant of forces on guides.	See p. 873.
575	What are cofferdams ? What are they used for ? Also enumerate the connections fitted on same.	Cofferdams are fitted between oil storage tanks and fresh water or cargo tanks with the object of preventing leakage from one to the other. The cofferdam consists of a narrow cross space arranged in the double bottom, and

No.	QUESTION.	ANSWER.
575	—*Continued*.	which is left clear. The fittings include access manholes and bilge pumping-out arrangement, air-vent pipe, sounding pipe, and, in some cases, an oil-pump connection for withdrawing leakage oil from the cofferdam and delivering to an oil tank space.
576	Describe a motor as fitted on ships' life-boats. Name the fuel used, and state how it is stored. What care is taken of the motor at sea, and what precautions regarding the magneto ?	See pp. 485, 492. The motor should be covered with vaseline and protected from the weather by water-tight covers. The magneto requires to be of damp-proof construction.
577	Describe compressed air and hydraulic reversing gear. How is the gear operated in port when no steam is available ?	See plate facing p. 84. See plate facing p. 1054.
578	Describe a type of oil separator. How are the water and oil discharge pipes arranged on the appliance ?	See pp. 535, 880.
579	Describe the position of stays in vertical type auxiliary boilers, and give the reasons for same.	See p. 847.
580	Where are fusible plugs fitted in Diesel engine practice ? Also give the melting point of the material of the plugs.	See p. 80.

No.	Question.	Answer.
581	How are the piston rods of D.A. Diesel engines protected and packed? Also show by a sketch the method of attaching the piston rod to the piston.	
582	Describe any system for the utilisation of waste heat. Give inlet and outlet temperatures, also approximate gain in B.T.U.'s.	The designer of the Clarkson exhaust boiler, Mr Thomas Clarkson, M.Inst.C.E., supplies the following formula for calculating the heat recovery in B.T.U.'s for either 2-cycle or 4-cycle engines :— **Rule,** **B.T.U.'s per hour** $= \dfrac{\text{B.H.P.} \times \text{C} \times \text{D}}{4}.$ **Where,** **C = 12 (4-cycle).** **C = 20 (2-cycle).** **D = Drop in exhaust gas temperature.** *Example.*—Calculate the total heat recovery in B.T.U.'s from a 2-cycle engine of, say, 2000 B.H.P., the exhaust gas entering the boiler at 600° F. and leaving at 350° F. Then, **B.T.U.'s per hour** $= \dfrac{2000 \times 20 \times (600° - 350°)}{4}$ $= 2500000$ **B.T.U.'s.** *Note.—* **B.T.U.'s per B.H.P. hour** $= \dfrac{2500000}{2000} = 1250.$
583	Mention the relationship which exists between the diameter and thickness of a Diesel engine cylinder liner.	
584	Describe any type of fire extinguisher used in modern practice. Give approximate pressure, period, and distance of the discharge jet.	

No.	QUESTION.	ANSWER.
585	Describe the Carbon Dioxide system of refrigeration. Show how pipes are led to the cold rooms, and how joints are made through water-tight bulkheads.	See plate facing p. 1054.
586	Sketch out and describe a distiller. How is it used, and what precautions are taken when using it ?	See p. 682.
587	Sketch a switchboard for a ship having electrical auxiliary machinery. Discuss circuits, and explain how the attendant is protected from injury.	See pp. 981, 982. When electrical motors are fitted, special circuits are provided, each being supplied with an ampmeter, volt-meter, fuses, starting switches, etc. Automatic circuit breakers are also fitted to prevent overload on the circuits, in addition to the motor starting switch devices. In the case of extensive marine electrical installations, the back of the switchboard, on which are arranged the exposed wires, terminals, and bus bars, is usually closed in and may be isolated by means of a door, which can be locked against admission as required.
588	Sketch out a fuel pump, and describe a method of control of the fuel from the pump to the cylinder fuel valve.	See pp. 19, 270, 556. See plates facing pp. 86 and 906-909.
589	Assuming the starting air pressure to be, say, 350 lbs., explain how this can overcome the compression pressure of, say, 5co lbs. ?	Starting air is usually carried for a period ranging from about 120° to 140° of the crank circle, and as the compression pressure of 500 lbs. is only maintained for about 15° of the crank circle, it will be evident

No.	QUESTION.	ANSWER.
589	—*Continued*.	that the inertia previously imparted to the moving parts by the starting air will easily overcome the resistance obtaining during the maximum compression period.
590	Explain the general principles of ventilation. Describe the condition of the air and the temperatures existing at various positions in the engine room. How is pollution of the air brought about ?	
591	Describe the operation of removing a propeller, also that of replacing same. What supervision is required in the case of propellers ?	
592	State the nature of the impurities found in fuel oil and in lubricating oil. What kind of defects might be caused by these ?	Impurities in fuel oil, such as heavy asphaltic deposits, may result in the closing up of the pulveriser ring openings, the result of which would be loss of power and smoking of the engine. Carbon deposits on the fuel valve might cause leakage. Water in fuel oil would lower the efficiency of combustion, and cause the engine to misfire or stop firing altogether. Air or oil vapour would result in an " air lock " or " gas lock," with the result that the engine might stop through want of fuel. Carbon deposits from lubricating oil would cause excessive wear in the liner at the position of the upper two or three rings. Tarry deposits might result in the piston rings becoming gummed up in the

No.	QUESTION.	ANSWER.
592	—*Continued.*	piston grooves with resultant "blow-past" leakage and heating up of the liner. Water present in the lubricating oil might lead to emulsification, in which condition the oil would lose most of its lubricating properties.
593	Sketch a silencer for a Diesel engine. Show how it is secured and how heat expansion is allowed for.	See p. 872.
594	Describe or sketch out a piston rod suitable for a double-acting Diesel engine.	See p. 104 and plates facing pp. 102, 753.
595	State the chief points to be noted during the shop trials of a Diesel engine.	The chief points to be observed and noted include the following :— 1, The B.H.P. to be measured by means of the Froude type water brake. 2, Indicator diagrams to be taken off and the I.H.P. calculated. 3, The mechanical efficiency to be found by dividing B.H.P. by I.H.P. 4, Draw cards and low springs diagram to be taken to check valve settings for firing pressures, also suction and exhaust pressures. Compression diagram may be taken with fuel shut off each cylinder in turn. 5, Temperatures of cooling water inlets and outlets, and exhaust gases to be taken, also colour of exhaust gases observed. 6, Fuel to be passed through measuring tanks and consumption per B.H.P. and I.H.P. hour worked out. 7, Compressor stage pressures and temperatures to be taken. After completing the trial run, all valve and pump settings should be checked, and, say, one piston drawn for examination of the rings, liner, etc.

No.	QUESTION.	ANSWER.
596	Referring to a three-stage air compressor, describe how overloading is prevented.	The overloading of compressors is prevented by the fitting of relief valves on the compressor cylinders and stage coolers, or by the fitting of safety discs of thin steel, which are designed to burst when the pressure exceeds a predetermined limit. The pressure may also be reduced by means of the leak-off connection by which a quantity of the compressor air may be blown off to the starting air tanks or to the atmosphere.
597	Name the physical properties required in the materials used for cylinders, liners, piston rods, blast air pipes, and air bottles.	The physical properties required in the materials for the parts named are :— *For Cylinder Castings.*—Good cast iron with high compressive and tensile strength. *For Liners.*—Special cast iron presenting a good machining surface and of high tensile strength, together with heat distortion resisting properties. *For Piston Rods.*—To be of superior mild steel with high compressive and tensile strength. *Blast Air Pipes.*—To be of mild steel and to possess ductility and strength. *Air Bottles.*—To be of solid drawn mild steel and to possess high tensile strength.
598	What is corrosion ? Give examples of corrosion as found in motor-driven vessels.	By the term " corrosion " is meant the wastage of materials due to chemical action, such as the combination of atmospheric oxygen with iron or steel. Corrosion may be found at the following positions :— 1, Air tanks, due to collected moisture (oxidation). 2, Air bottles, due to want of regular drainage (oxidation). 3, Cooling jackets in which sea water is circulated, due to chemical action from acids present. 4, Fuel valves sometimes corrode at the position of the seating, if water is present in the fuel (oxidation). 5, Sulphur when present in the fuel, together with moisture, tends to cause corrosion of the exhaust valve owing to the chemical formation of SO_2. 6,

No.	QUESTION.	ANSWER.
598	—*Continued*.	If the lubricating oil contains sulphur constituents, or animal acids, corrosion may take place on the bottom end or main bearings.
599	Describe the details of a compression plate as fitted in Diesel engine practice.	In S.A. engines thin plates are fitted under the foot of the connecting rod to permit of alteration in the clearance volume of the cylinder. If plates are added, the clearance volume will be reduced, and the compression pressure increased, and vice versa. The thin plates referred to are held in position by means of suitable dowels.
600	Make a sketch of an engine sole plate. Show the parts which are machined and how it is secured to the tank tops.	See pp. 273, 274.
601	Sketch a light spring diagram as taken off a 4-cycle engine. Describe the various points on the card.	See pp. 312, 320, 321.
602	Referring to starting air for a Diesel engine, describe fully how overlap is provided for, and why.	Referring to starting air, by the term "overlap" is meant the period during which the starting air valves of any two cylinders are both open at the same time. This provision is made to ensure that no break will occur in the starting air impulse given to the engine. The angle through which starting air is carried depends on (1) the number of cylinders fitted, and (2) the cycle, whether two or four. Starting air may be admitted until 140° A.T.C. in the case of a 6-cylinder 4-cycle engine, and, say, 110° A.T.C. in a 6-cylinder 2-cycle engine, the air admission angle being, say, 3° to 7° A.T.C. Overlap, therefore, is provided with the object of admitting starting air to one cylinder valve before the other cylinder valve has closed, and in this way ensure the continuity of the starting effort. The overlap angle ranges to 10° to 15° of the crank circle.

No.	QUESTION.	ANSWER.
603	Describe the piston of a hot-bulb engine. How is the connecting rod secured, and how are the rings machined and fitted ? What allowance is made for fitting the rings ?	See pp. 472, 577, 816.
'604	Describe how to set the fuel pumps at bottom " centre " position, independently of the flywheel marking.	1, Turn engine so that pump is nearly at " full out " position, and with a trammel or pair of dividers and a fixed point on pump body, mark pump crosshead. 2, Next refer to engine and, selecting a crank which happens to be approaching the top centre, note the number of degrees on flywheel marking, B.T.C. 3, With turning gear turn engine until the pump plunger completes the out-stroke and comes back until the trammel marks again coincide, and note degrees A.T.C. described by crank. 4, Take total degrees described, and turn engine back exactly half this amount, at which position the flywheel may be marked at index pointer " fuel pumps on B.C." *Example.*—With mark on pump crosshead, the crank of, say, No. 8 cylinder is 20° B.T.C., and after turning engine as described, the crank is at 40° A.T.C. Then, $\dfrac{20° + 40°}{2} = 30°$. The crank will therefore require to be turned back for 30°, at which position the fuel pumps will be exactly at bottom (or " out ") dead centre. The tappet clearance (say ·004 in.) will require to be adjusted for this position with gear in running position and with governor arms out.
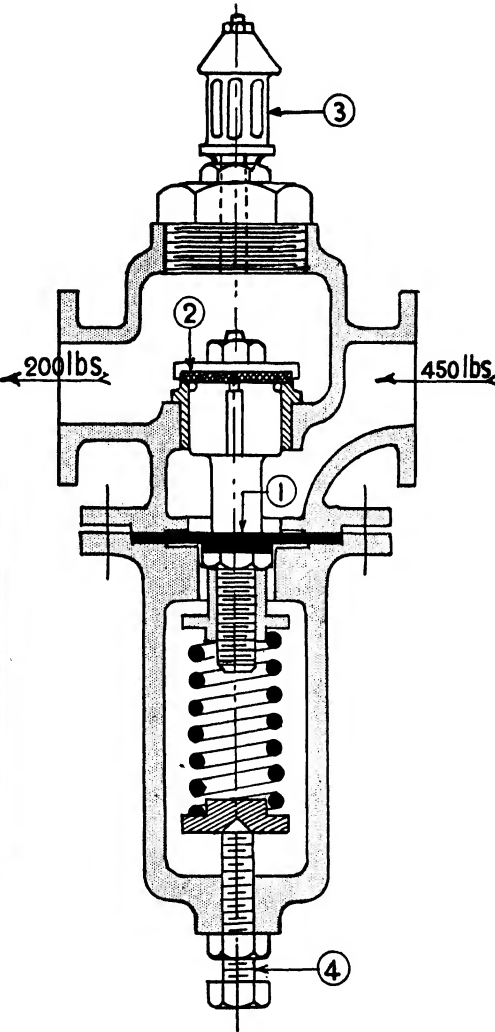
No.	QUESTION.	ANSWER.
605	What is taken into consideration when designing the starting air tanks of a motor vessel? What governs the minimum supply of starting air stored? What is the average air storage pressure, and the minimum pressure on which the engine will move? Give type of engine, diameter, and number of cylinders, also stroke, referred to.	The starting air capacity usually provided for ranges from 6 to 7 times the combined cylinder volumes of the engine, and is designed to allow for from 12 to 14 starting impulses, ahead and astern, without replenishing. The lowest pressure at which an engine will manœuvre is about 150 lbs. per $\boxed{n}$ or thereabout.

Example.—Six-cylinder, 4-cycle engine, cylinder dia.$=24\frac{1}{2}$ in., stroke$=38$ in. Assuming air to be carried, say, ·8 stroke and 3 cylinders on air per revolution, and a starting air pressure of, say, 350 lbs. per $\boxed{n}$.

Then, cylinder volume $= \dfrac{24\cdot5^2 \times \frac{11}{14} \times 38}{1728}$
$= 10\cdot4$ (nearly).

Combined volume $= 10\cdot4 \times 6 = 62\cdot4$.
Tank capacity required $= 62\cdot4 \times 6 = 374\cdot4$ cub. ft.
Air per rev. $= 10\cdot4 \times 3 \times \cdot8 = 25$ cub. ft.
So that,
For 12 starts, $25 \times 12 = 300$ cub. ft. used.
Applying Boyle's Law $P_1 \times V_1 = P_2 \times V_2$,
where $P_1 = 350$
,, $V_1 = 374\cdot4$
,, $V_2 = (374\cdot4 + 300) = 674\cdot4$ cub. ft.
Then, Lowest starting air pressure (P_2)
$$P_2 = \frac{374\cdot4 \times 350}{674\cdot4} = 194 \text{ lbs. Ans.}$$

Note.—In the case of 2-cycle engines the air start may only be carried for, say, ·6 stroke.

No.	QUESTION.	ANSWER.
606	Sketch out and describe a type of packing for the piston rods of double-acting engines.	See pp. 115, 129, 895.
607	Describe and sketch out the chain drive for camshafts. Give details and dimensions of links and pins, etc.	See p. 871.

No.	QUESTION.	ANSWER.
608	Mention the physical properties of the materials used for piston rods, exhaust valves, and propellers.	See p. 754. Materials for piston rods should possess properties of tensile and compressive strength, together with ductility. The material for exhaust valves requires to possess properties of resistance to the erosive effect of the high temperature and velocity of the exhaust gases. The material for propeller blades should possess properties of strength, toughness, and the ability to develop a smooth skin surface polish.
609	Sketch out, with dimensions, a Cochrane type vertical auxiliary boiler.	See pp. 814, 845, and plate facing p. 1054.
610	Describe how the quantity of fuel oil in the tanks is measured. What precautions are taken against overflow of tanks when filling ?	See p. 312. By means of the pneumercator tank-gauge. Expansion trunks are provided to allow for overflow, also an overflow pipe into a separate tank. See pp. 884-886.
611	Describe the Büchi system of turbo-charging of 4-cycle engines. What " overlap " period is allowed ?	See pp. 783-789.
612	Mention the constituents of fuel oil and of lubricating oil, and explain the differences between the two.	See pp. 409, 444, 629, 633. Lubricating oil should be of mineral quality, with high flash point, high viscosity, and be non-carbonising. The specific gravity at 60° F. to range from ·87 to ·915.
613	How is lubricating oil circulated in Diesel engines ? Give the pressures at various points, and compare the consumption with that of steam engines of equal power.	See p. 634. In Diesel engine practice the lubricating oil consumption averages about ·5 of one per cent. of the fuel consumption. In steam turbine practice the lubricating oil consumption is equal to about ·2 of one per cent. of the fuel consumption, or even less. The lubricating oil pressure ranges from 10 to 25 lbs. per $\square$ in ordinary practice.
614	What are electrical accumulators? What are they used for, and what attention do they require ?	See p. 937.

No.	QUESTION.	ANSWER.
615	Sketch and describe the flywheel for a heavy oil internal combustion engine. How is it fitted, secured, and what is its object ? Also describe its action.	The flywheel, of cast or forged steel, if heavy, say over 7 tons, is usually constructed in halves, the boss being secured to the shaft coupling by means of double keys, as shown in sketch (No. 899), the halves of the wheel being bolted together at the boss, and the rim locked in position by means of double cottars, which are finally tightened up and secured in place. The functions of the flywheel are as follows :— 1. To store up energy and so prevent either racing at high revolution speeds or sudden reduction of engine revolution speed when the load falls off. 2. To function as a turning wheel, and for this purpose the rim is toothed. 3. To permit of setting of the valve timings, the top-centre positions of the various pistons being indexed on the rim, which is also marked off in degrees of a circle (360°). See pp. 55, 899. NOTE.—When the load is reduced during, say, racing, the flywheel inertia acts to keep down the revolutions, and when the load is increased the flywheel inertia acts to bring up the revolutions to an average. In other words, the flywheel stores up energy during full-power revolutions and releases the same when the revolutions fall off, and in this manner also tends to reduce torsional vibrations on the main shafting. See p. 868. ✗
616	What emergency power is required on vessels having a heavy oil internal combustion engine as its prime mover ? What percentage of the main engine power does	Emergency power is usually provided for light, steering gear, and bilge pumping purposes. Emergency bilge pumps are fitted in the engine-room, stokehold, etc., and in some cases hand-power " Downton " type pumps are placed forward, aft, and amidships, although in modern vessels

No.	Question.	Answer.
616	*—Continued.* this represent? Where and how is the power generated, and how is it used ?	this type of pump is now obsolete. Low-power electrical generators may also be fitted above the main deck, to supply light, and in Diesel-engined vessels a hot-bulb engine is often provided to supply power for light or electric motor-driven pumps. Electrical storage batteries of the " Exide " type are often supplied to provide emergency lighting and steering-gear power. Emergency power is equal to about ·5 per cent. of the main engine power.
617	Assume that the fuel valve and pump clearances are unaltered, what would be the effect of wear down of the crank and crosshead bearings on the running of a single-acting engine ?	If the top end, bottom end, or main bearings wear down, the piston clearance volume will be increased in the cylinders. The effect of this will be to reduce the compression pressure and temperature giving faulty ignition and poor combustion in the cylinder. The exhaust gases would be dark in colour, and the fuel consumption per I.H.P. hour would rise. The total power developed would fall off.
618	Describe the system of bilge and ballast pumping for a large vessel having a heavy oil internal combustion engine for propulsion. Sketch and describe the general lay-out. What is the capacity of the various pumps? Describe an alternative arrangement in place of the bilge injection as fitted in steam vessels ; what are bilge pipes made of ? How are the pipes led to the holds?	*Example.—* **S.H.P. = 10000.** **Displacement = 9000 tons.** **2 Main Bilge pumps fitted, each of 15 H.P.** **Combined output = 220 tons per hour.** **1 Emergency Bilge pump of 15 H.P.** **Output = 110 tons per hour.** **1 Ballast pump, with bilge connection, of 30 H.P.** **Output = 200 tons per hour.** **Total tons discharge per hour** **= 220 + 110 + 200 = 530 tons.** **Total pump power available** **= 15 + 15 + 15 + 30 = 75 H.P.** **Referred to displacement.** **Then,** $\dfrac{530 \times 100}{9000}$ **= 6 per cent. (nearly).** **Referred to S.H.P.** **Then,** $\dfrac{75 \times 100}{10000}$ **= ·75 per cent.**

No.	QUESTION.	ANSWER.
618	—*Continued*.	Therefore the combined bilge and ballast pump capacity per hour is equal to about 6 per cent. of the displacement, and the pump power is equal to ·75 per cent. of the total engine power. Pipes are often constructed of iron or mild steel, the diameter ranging from 3 to 4 in. and are led as far away from the ship's side as possible. Also see p. 919.
619	Describe any method of transferring the action of the steering wheel to the steering engine situated aft, what type of gearing requires expansion couplings, and state faults liable to occur through neglect of these ?	See pp. 516-525.
620	Sketch and describe a gear pump. Show direction of rotation of the wheels, also the position of inlet and outlet, what governs the size of same, also the output pressure of pump and efficiency ?	See pp. 856, 893.
621	Describe an electric motor for driving any auxiliary machine. How is the motor wound, and why is this type of winding used in preference to any other winding ?	See pp. 989, 993. See plate facing p. 989. A shunt wound motor runs at nearly constant revolution speed at all loads, and is therefore best suited for power transmission where load variation is not excessive. For heavy intermitting loads, compound winding would be advisable.
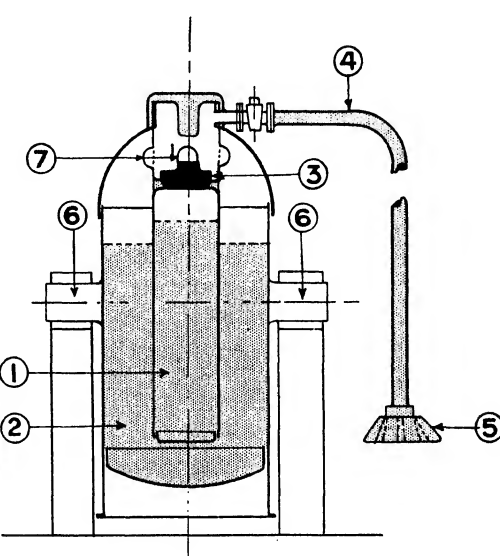
No.	QUESTION.	ANSWER.
622	Describe or sketch out an air pressure reducing valve as fitted in Diesel engine practice. How is the reduced pressure regulated? What materials are employed for the valve discs? For what purposes is reduced air pressure required?	

200 lbs.   450 lbs.

No. 486.—Air Reducing Valve.

1, Rubber disc.
2, Woodite disc.
3, Relief valve (on low-pressure side).
4, Spring adjusting screw and nuts.

No.	QUESTION.	ANSWER.
622	—*Continued*.	The compression given to the spring controls the opening of the valve, and if the opening increases, the higher pressure obtained on the other side acts to close down the valve to normal lift, and therefore the correct reduced pressure will be maintained. Reduced air pressure is used for whistle purposes and for clearing of sea injection perforated inlet plates, also for operation of the reversing gear, etc.
623	What are the duties of the chief engineer of a large power Diesel twin-screw vessel (*a*) at sea, (*b*) in port ? What are the second engineer's duties ? Detail the number of men, where each should be placed, and duties of each while on watch, also in port when doing general maintenance work.	The chief engineer is required to interview the captain and obtain all necessary information *re* the coming voyage, duration of same, and amount of fuel required plus an additional allowance for emergencies. While in port to see all necessary machinery overhauling carried out. During the voyage to allocate the watches and duties of the engine-room staff, say two engineers on each watch and one electrician. To have indicator diagrams taken off, and after working same to note and record results. To keep a daily record of engine details, such as temperature of exhaust gases, piston and jacket cooling water outlets. Also to record fuel and lubricating oil used, power developed, and speed obtained. The second engineer requires to arrange the routine work of the staff as required by the length of voyage and time in port. In port the third and sixth engineers may be detailed to lift cylinder covers, withdraw pistons, gauge piston rings and liners, replace fuel or other valves as may be required, etc. The fourth and eighth engineers are usually appointed to adjust guides, crosshead, and crankpin brasses, main bearings, etc.

No.	Question.	Answer.
623	—*Continued.*	The usual practice is to completely overhaul at least one cylinder of the engine at each terminal port. The fifth engineer to look after and keep in order one main compressor. The seventh engineer to be on night duty, and other junior engineers, if any, to attend to the auxiliary engines, blast-air bottles, starting air tanks, and ordinary day work, pumping up fuel tanks, etc. See also p. 903.
624	What is meant by transverse meta-centric height of a vessel ? Could this be changed by altering the ballast or by allowing bilge water to accumulate ?	See p. 920.
625	How are water-tight bulkheads fitted to the sides and bottom of a tank ? Discuss the rivets and riveting.	See p. 910.
626	Sketch and describe a hatch coaming as fitted to an oil-carrying vessel or to a deep tank.	See p. 910.
627	Describe supercharging as fitted to a heavy oil engine. Why is it adopted ?	In the Büchi system of supercharge the exhaust gases are utilised to drive a single-stage turbine, the latter being direct coupled to a two-stage air blower. The pressure of the exhaust gas averages about 3 to $3\frac{1}{2}$ lbs. per square inch, and the temperature ranges from 700° to 800° F. The slightly compressed air discharged from the blower is led through piping to the air inlet valves

No.	QUESTION.	ANSWER.
627	—*Continued*.	of the 4-cycle engine. The pressure of the air entering the cylinders averages about 3 lbs. per square inch, and as the weight of air charge is thus increased, additional fuel can be consumed with high thermal efficiency and a power output increase of as much as 50 per cent.
		Adjustments Required.
		1. Air piping from blower delivery to cylinder inlet valves.
		2. Increase of air inlet and exhaust overlap period to, say, 110° of the crank circle, and requiring cam alteration.
		3. Cylinder clearance volume to be increased from, say, 8 to 10 per cent. of stroke volume to keep down the initial pressure.
		4. Fuel to be carried further on the working stroke for the same reason. The initial pressure should remain constant, but the M.I.P. should show an increase.
		Note.—The turbine and blower function equally for ahead and astern running, so that no by-passing of the gases becomes necessary when manœuvring.
		5. The exhaust manifold, in place of being water-cooled to extract the heat, may be insulated to retain the heat. See pp. 783-789.
628	Describe how propeller type and centrifugal type fans are constructed, also where they are used on board ships. Give approximate diameter and speed of each type.	Centrifugal type fans are employed for purposes of boiler forced draught, also for general ventilation on the " Thermotank " system. For local cabin ventilation high revolution small motor-driven fans of the propeller type are usually fitted. In the " Thermotank " system the fans are placed on the upper deck and are

No.	QUESTION.	ANSWER.
628	—*Continued*.	driven by electric motors, the revolution speed ranging from 350 to 2500 per min. In the " Thermotank " system the air can be cooled in tanks by means of brine pipe circulation, or heated by steam, as may be required. In the Howden forced-draught system the fans are usually steam driven, and run at 250 revs. per min. or thereabout. Centrifugal and propeller ventilation fans range in size from 18 to 42 in. diameter, the volume of air delivered being from 3000 to 16000 cub. ft. per min., and depending on the water-gauge suction measurement carried.
629	What fire appliances are necessary on board a vessel using oil fuel ? Describe a portable fire extinguisher.	Fires may be extinguished by the following methods :— 1. By the use of CO_2 froth, such as " Phomene," " Petrofoam," etc. 2. By the use of water-pressure sprinklers on the " Grinnell " system. 3. By the use of CO_2 gas which is discharged direct into the affected compartment of the vessel. In the CO_2 froth system, such as " Phomene," a container of 34-gal. liquid capacity is required by the Board of Trade for Diesel-engined vessels which are fitted with an auxiliary steam boiler. It may be noted that in all cases of fire fighting the exclusion of atmosphere oxygen is the object aimed at, as without a supply of oxygen a fire cannot exist. In the " Phomene " system the container, of lead-coated sheet steel, is fitted with an internal pipe, which is closed by a lead valve when in the upright position, the container

No.	QUESTION.	ANSWER.
629	—*Continued*.	being supported on a pair of trunnions, as shown in sketch. The inner tube

No. 487.—"Phomene" Fire Extinguisher.

1, Inner container (acid).
2, Outer container (alkali).
3, Lead valve (loose seated).
4, Discharge flexible hose.
5, Spreader discharge nozzle.
6, Trunnions.
7, Openings in inner container.

contains an acid solution, and the outer container shell an alkali solution in the proportions of acid 1 part to alkali 3 parts.

When the appliance is inverted the valve drops out of position, and the two chemicals combine to generate CO_2 in a semi-solid condition under pressure.

The froth is discharged at the outlet, and is led through flexible piping to a flat sprayer or " spreader." The

No.	QUESTION.	ANSWER.
629	—*Continued.*	sprayer directs the jet on to the surface of the flame, and a layer of froth is deposited, which functions to blanket off atmospheric air and thus starve out the fire.
		Capacity of container = 34 gals. liquid. **Output of container = 270 ,, froth.** **Pressure = 200 lbs.** **Length of jet = 60 ft.** **Duration of jet = 15 mins.**
		Note.—The water-sprinkler system is employed for passenger cabins and accommodation. The CO_2 gas system is employed for cargo holds, and the CO_2 froth system for machinery and boiler compartments. See p. 377.
630	In a large heavy oil engine what are the stresses on the top and bottom end bolts of (*a*) single-acting, 4-cycle type; (*b*) double-acting type. Would this affect the design of the bolts ?	In a single-acting 4-cycle Diesel engine the top end and bottom end bolts are subject to low tensile stress on the downward air suction stroke of the cycle. On the firing stroke, compression stroke, and exhaust stroke the bolts are free of either tensile or compressive stresses. In a double-acting 4-cycle engine the bolts are subject to tensile stress on the bottom firing stroke and bottom compression stroke. The bolts would therefore require to be designed accordingly, and should be heavier for double-acting engines.
631	What are " stealer " plates, also panting beams and stringers? Where are they placed and what purpose do they serve ?	See p. 912.
632	A tank has been used for fuel oil and is now going to be used for cargo. What	Before a tank that has been used for carrying fuel oil and is now going to be used for cargo is entered, it should be steamed out and repeatedly filled

No.	QUESTION.	ANSWER.
632	—*Continued.* precautions as regards examination should be taken when entering same ? Also mention advantages and disadvantages of (*a*) a portable electric lamp connected to the ship's mains ; (*b*) a portable lamp with battery complete ; and (*c*) a Davy safety lamp.	and emptied with water, in this way removing any dangerous gas that might be present. A test with a Davy safety lamp should always be made before entering the tank to see that sufficient oxygen is present in the air of the tank to support life, and that no explosive gas is present. After this has been done and found correct, the tank may be entered and the final cleaning undertaken. Advantages and disadvantages of the various means of illumination for examination of the tank are as follows :— A Davy lamp gives an indication of the ability of the air to support life, also the presence of explosive gases, but gives a poor, though safe, light. A portable lamp with battery gives no indication of foul gas present ; gives good illumination and, if properly constructed, is safe. A portable lamp from the mains is dangerous, as the lead may get damaged and cause a spark which might lead to an explosion.
633	There is an instrument devised for detecting fire in the holds, etc., of vessels. Describe its action.	In one system of fire detection a thermostatic device is fitted in each cabin or hold, and on a predetermined temperature being reached the expansion due to heat causes an alarm bell to ring and actuate an indicator on the bridge, giving the number of the compartment in danger. Another system consists of a series of small tubes led from the various compartments and holds to a receiver box on the bridge. A small electric motor-driven fan functions to draw samples of air at regular intervals from each compartment, and a lighting arrangement on the bridge makes any smoke present become visible, the smell also being noticeable. When

No.	QUESTION.	ANSWER.
633	—*Continued*.	smoke is emitted, the alarm bell is automatically actuated ; the position of the affected compartment also being registered.
634	Why are balance weights fitted on the crankshafts of Diesel engines ? Where are they placed ? Show by sketches how the weights are attached.	See p. 894.
635	What method of ventilation is employed in the pump-room of an oil tanker ? Describe the precautions taken for the thorough ventilation of this compartment.	Ventilation of the pump-room in a tanker is usually carried out by means of two steam ejectors of the " Korting " or other type, with a suction pipe diameter of, say, $4\frac{1}{2}$ in. and the steam ejector 3 in. diameter. The suction or inlet pipe is led down to within 9 in. of the tank bottom, and the gas is entrained and discharged at a high-level position to the atmosphere. The usual vapour escape pipes are fitted in addition to the steam ejectors described, also steaming-out connections for cleaning the tanks after pumping out the contents. Also see p. 892.
636	Describe a type of ship's lifeboat davit other than the post type. Explain the action of same and mention the care required to maintain the working parts in good order.	See p. 921.
637	Sketch and describe the stern frame of a single-screw vessel, showing how it is attached to the hull. Mention the parts which require to be machined.	See plate facing p. 916. Machined parts are :— 1, Gudgeons. 2, Hole for stern tube. 3, Facing for transome beams. 4, Foot where fitted to keel plate.

No.	QUESTION.	ANSWER.
638	Describe or sketch how a shunt-wound type electric motor is reversed, and explain the principle which causes the reversal of rotation.	See p. 989.
639	Describe briefly the Isherwood system of longitudinal ship framing. What are the advantages claimed ?	See plate facing p. 911.
640	Describe the electro-hydraulic type steering gear. What is the pressure carried, and what emergency gear is provided ?	See pp. 525-532, 820-826.
641	Describe the types of lamps suitable for cabin or saloon illumination. State the difference between a vacuum lamp and a " gas-filled " lamp, also mention the materials employed in the construction of each.	Modern incandescent lamps are of the " gas-filled " type, Nitrogen gas or Argon gas being employed. These gases are known as dead or inert gases and do not support combustion. The filaments used are of metallic composition, either of Tungsten or other suitable metal, and offer a high resistance to current flow, which induces a white light without combustion taking place. Gas-filled incandescent lamps usually give out one candle-power for one half-watt current consumption. The power of a lamp is now always expressed in watts, such as 40 watts, 60 watts, 100 watts, etc., so that $$\frac{\textbf{Watts}}{\textbf{Volts}} = \textbf{Amps.}$$ A 60-watt lamp will therefore use ·54 amp. of current at 110 volts, as $$\frac{60}{110} = \textbf{·54 amp.}$$

No.	Question.	Answer.
642	Describe the telemotor system of steering gear control. How is the system charged, how is expansion of the fluid allowed for, and what kind of fluid is used ?	See pp. 516-525.
643	Describe how transverse W.T. bulkheads are fitted to the sides and bottom of tanks. Give sketch of the riveting.	See p. 910; also Question No. 625.
644	Describe and sketch the rudder of your last steamer, showing how the rudder stock passes through the ship's counter, etc., also show how wear down is allowed for at the pintles, and mention the angle through which the rudder is arranged to turn. Explain how the movement is checked.	See pp. 685, 917.
645	Describe the process of boring out the stern post to receive the stern tube. How are the centres for the boring bar determined ?	See p. 918.
646	Describe how to draw the propeller shafts of a twin-screw vessel sternways.	To draw a propeller shaft sternways the shaft has at its inboard end a special heavy muff coupling fitted on a taper, with a key similar to that on the propeller-shaft end. This coupling has recessed into it, and

No.	Question.	Answer.
646	—*Continued*.	below the flush, a nut securing it to the shaft. To withdraw the shaft, the first thing required to be done would be to support the outboard end, break the coupling and move the shaft out until the nut at the inner end could be slackened and the coupling drawn off the taper. The shaft could then be withdrawn completely, care being taken as it came out to support it suitably and at the correct height to make withdrawal easy.
647	Describe how the fuel supply is controlled in Diesel engines. What means are provided to prevent racing? Mention the type of engine described and give the approximate B.H.P.	The fuel supply to each cylinder is regulated by means of the fuel pump, the tappet rod of which functions to prevent the suction valve from seating during a portion of the delivery stroke, the surplus fuel being then returned to the suction side. The tappet rod lift is under both hand and governor control. The fuel pump measures the quantity of fuel, and the cylinder fuel valve the *timing* of the fuel-injection period. A 4-cycle H. & W. Diesel engine may consist of, say, eight cylinders, each 25 in. diameter and 40 in. stroke, the revolutions being 110, and the M.I.P. about 85 lbs. ☐. This engine would develop about 1600 I.H.P., and allowing a Mechanical Efficiency of, say, 78 per cent., 1250 B.H.P. The fuel consumption may be rated at, say, ·4 lb. per B.H.P. hour.
648	Describe briefly how insulation is carried out in refrigerated ships' holds. How are hatches fitted and secured? What materials are employed for insulation?	The walls of refrigerated chambers usually consist of hollow-tongued and grooved wood casing boards, within which granulated cork is forced under compressed air pressure to a density of 7 lbs. per cubic foot, the depth of insulation being about 10 in. The hatch covers, also hollow and insulated, are fitted in wedge-shaped sections, these being battened hard

No.	QUESTION.	ANSWER.
648	—*Continued*.	down in place, a sprinkling of sawdust being applied to the jointing edges of the sections. In some cases rubber is employed as a jointing material. The hatches are sometimes clamped down and wedged in place. After discharging, the holds are prepared to receive the new cargo by being thoroughly washed out to remove the contaminating liquids left behind from animal or fruit products, etc. After washing, the holds are dried by means of air, and are finally cooled down to the temperature required for the new cargo.
649	Describe how to estimate approximately the calorific value of the fuel when running under service conditions at sea.	Measure fuel consumed during a period of, say, two hours' running, by means of settling tank gauge glass calibrations. Take off indicator diagrams and calculate the total I.H.P. of the engine. The thermal efficiency may be taken as, say, 34 per cent. on B.H.P. basis, which figure represents good modern Diesel engine practice.

Then,

$$\text{Fuel per I.H.P. hour} = \frac{\text{Tons} \times 2240}{\text{B.H.P.} \times 2}$$

$$= \text{Lbs. fuel.}$$

Therefore,

$$\text{Lbs. fuel} \times \text{B.T.U.'s} \times 778 \times \frac{34}{100} = 33000 \times 60.$$

So that

$$\text{Calorific value} = \frac{33000 \times 60}{\text{Lbs. fuel} \times 778 \times \cdot 34}$$

$$= \text{B.T.U.'s per lb.}$$

Example.

I.H.P. $= 2000$.

Fuel per 2 hours $= \cdot 7143$ ton.

$$\text{Fuel per I.H.P. hour} = \frac{\cdot 7143 \times 2240}{2000 \times 2}$$

$$= \cdot 4 \text{ lb.}$$

Then,

$$\text{Calorific value} = \frac{33000 \times 60}{\cdot 4 \times 778 \times \cdot 34}$$

$$= 18714 \text{ B.T.U.'s per lb.}$$

No.	QUESTION.	ANSWER.
650	Give explanations of "apparent slip," "negative slip," "real slip," and "thrust deduction."	(a) Apparent positive slip.

(a) Apparent positive slip.

Example.
  Ship's speed in still water = 11 knots.
  Propeller speed by counter = 12   ,,
Then,

$$\text{Apparent slip} = \frac{(12 - 11) \times 100}{12}$$

$$= 8\cdot33 \text{ per cent. positive.}$$

(b) Apparent negative slip.
    Assume a following sea speed of, say, 2 knots.
Then,

$$\text{Apparent slip} = \frac{12 - (11 + 2) \times 100}{12}$$

$$= - 8\cdot33 \text{ per cent. negative.}$$

Note.—

$$\text{Engine speed} = \frac{\text{Pitch} \times \text{Revs.} \times 60}{6080}.$$

(c) "Real" or "actual" slip.
    Assume wake speed = 1½ knots.
Then,

$$\text{Real slip} = \frac{(12 + 1\cdot5 - 11) \times 100}{12}$$

$$= 20\cdot8 \text{ per cent.}$$

Real slip is therefore equal to the sum of the apparent slip per cent. and the wake speed per cent. By "wake" is meant the effect produced by the closing in of the water at the stern as the vessel moves forward and which exerts a pressure in the same direction.

Thrust Deduction.—The action of the propeller in drawing water away from forward to aft reduces the beneficial effect of the wake speed, as mentioned, and this difference is known as "thrust deduction."

| 651 | Describe an independent type bilge pump. If steam, describe how the cylinder valves are actuated. | Independent type emergency bilge pumps are often of the "Weir," "Drysdale," or "Dawson and Downie" types, and may have a capacity of from 60 to 120 tons per hour. |

No.	Question.	Answer.
651	—*Continued.*	The pumps are sometimes fitted in duplex form, and may be either steam, Diesel, or electric-motor driven. If motor-driven, the motor drive revolutions are reduced to suit the speed of the pump crankshaft, the speed reduction being effected by either pinion and pinion wheel gear, or by chain drive, the gear down ratio being about 6 to 1. Submersible type emergency horizontal centrifugal bilge pumps are sometimes totally enclosed for water tightness and are electric-motor driven, the current being supplied by the emergency hot-bulb engine-driven dynamo situated on the main or other deck above. The Drysdale patent S.O.S. emergency bilge pump of this type, and approved by Board of Trade, is constructed with a special air bell in which the motor is fitted, and if flooding takes place the air is compressed in the bell and thus prevents the admission of water into the motor casing. See plate facing p. 887 ; also pp. 887-889.
652	Sketch out indicator diagrams as taken from a 3-stage air compressor, and give average pressures and temperatures existing at each stage of compression before and after cooling takes place.	See pp. 864-867.
653	Describe a system of hydraulic control of watertight bulkhead doors.	See pp. 922-934.

DATA FROM ACTUAL PRACTICE

No. 1.   8-Cylinder 4-Cycle Double-Acting Engine

Cylinder dia. = 840 mm.
,,   stroke = 1500 mm.
Blast air pressure = 56 atmospheres.
Revolutions = 108.
Speed = 16·8 knots.

No. 3.—Cylinder (Starboard).

M.I.P. (top)   = 6·12 kg. cm².
,,   (bottom) = 5·45   ,,
I.H P. (top)   = 612
,,   (bottom) = 461
Average M.I.P. (top)   (all cylinders) = 6·03 kg. cm².
,,   ,,   (bottom)   ,,   = 5·32   ,,
Exhaust temperature (top)   = 660° F.
,,   ,,   (bottom) = 660° F.
Jacket water   = 133° F.
Piston cooling   = 151° F.
Fuel consumption per I.H.P. hour (main engines) = ·299 lb.
Calorific value of fuel = 19300 B.T.U.'s per lb.
Flash point = 190° F.
Specific gravity at 60° F. = ·86.

No. 2.   6-Cylinder 4-Cycle Double-Acting Engine

No. 3.—Cylinder (Port).

M.I.P. (top)   = 6·1 kg. cm².
,,   (bottom) = 6·1   ,,
I.H.P. (top)   = 320
,,   (bottom) = 271
,,   (top)   (all cylinders) = 1921
,,   (bottom)   ,,   = 1604
                        ————
                I.H.P. Total = 3525
Revolutions = 94

No. 3.—Cylinder (Starboard).

M.I.P. (top)   = 5·9 kg. cm².
,,   (bottom) = 5·9   ,,
I.H.P. (top)   = 310
,,   (bottom) = 263
,,   (top)   (all cylinders) = 1887
,,   (bottom)   ,,   = 1583
                        ————
                I.H.P. Total = 3470

Revolutions = 94·2.

Compressor pressures, L.P. = 40   lbs. 🔲.

      ,,   ,,   I.P. = 142·5   ,,

      ,,   ,,   H.P. = 854   ,,

Exhaust temperature (top)   = 644° F.

      ,,   ,,   (bottom) = 644° F.

Piston cooling = 114° F.

Fresh water circulation = 108° F.

Lubricating oil temperature at coolers.

    Inlet   = 100° F.

    Outlet = 90° F.

Lubricating oil pressures.

    Filter = 38 lbs. 🔲.

    Main bearings = $21\frac{1}{2}$ lbs. 🔲.

    Pistons = 17 lbs. 🔲.

    Oil cooler = 24 lbs. 🔲.

No. 3.

Firing Sequence in D.A. Engines. } (B. & W., D.A., T.S. 4-cycle engine (8 cylinders).)

Ahead
{
Port   T.(1, 8)   T.(4, 5)   B.(1, 8)   T.(3, 6)   B.(2, 7)   B.(3, 6)   T.(2, 7)   B.(4, 5).

Starboard   T.(1, 8)   B.(4, 5)   T.(2, 7)   B.(3, 6)   B.(2, 7)   T.(3, 6)   B.(1, 8)   T.(4, 5).

The ahead sequence of firing for the port engine is the astern firing sequence for the starboard engine, and vice versa.

It will be noted that the cylinders fire in pairs, top and bottom.

The cycle is as follows :—

D.A. 4-CYCLE ENGINE

Number of Stroke.	Top.	Bottom.
1	Firing.	Compression.
2	Exhaust.	Firing.
3	Induction.	Exhaust.
4	Compression.	Induction.

There are thus two firing strokes in one revolution per cylinder followed by an " idle " revolution, the firing intervals being 180° and 540°.
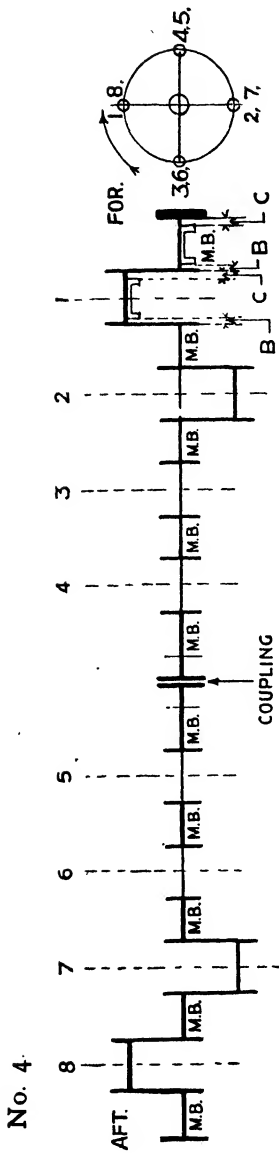
No. 488.—Arrangement of Cranks in 8-Cylinder 4-Cycle Engine.

Firing Sequence—Ahead, 1, 3, 2, 4, 8, 6, 7, 5.

„   Astern, 1, 5, 7, 6, 8, 4, 2, 3.

The minimum play allowed in main bearings = 2 mm. aft B, and = 18 mm. forward C.

SPEED, REVOLUTIONS, AND B.H.P. 6-CYLINDER 2-CYCLE ENGINE

Speed in knots – – – –	11·58	13·99	15·21	15·91
Revolutions per minute – –	80·4	100	109·3	114·7
B.H.P. – – – – –	2628	4945	6365	7785
Blast air pressure – – –	750	875	937	982
Scavenge air pressure in inches mercury – – – –	1·7″	1·75″	1·8″	2·1″

Remarks.

1. With increase of revolutions the speed of the ship is less than directly proportional, for the reason that the slip per cent. increased with revolution speed.

2. To increase the revolutions from 80·4 to 114·7 required an increase of B.H.P. from 2628 to 7785, or about 3 to 1 ratio, which works out as approximately as the revolutions cubed.*

3. The blast air and scavenge air pressure both increase with increase of power developed.

Example.—B.H.P. = 2628 at 80·4 revolutions, find B.H.P. at 114·7 revolutions.

Then, as $80·4^3 : 114·7^3 :: 2628$ (B.H.P.) : 7623 (B.H.P.).

The actual power developed was 7785 B.H.P.

Firing Sequence.

For twin screw 6-cylinder D.A. 4-cycle engines.

Port.—T1, B3, T2, B1, T4, B2, T6, B4, T5, B6, T3, B5.

Starboard.—T1, B2, T3, B1, T5, B3, T6, B5, T4, B6, T2, B4.

Valve Timing.

Top	Fuel valve	opens 7° B.T.C.	closes	35° A.T.C.
	Air inlet valve	,, 22° B.T.C.	,,	31° A.B.C.
	Exhaust valve	,, 45° B.B.C.	,,	20° A.T.C.
	Air starting valve	,, 11° A.T.C.	,,	134° A.T.C.

Bottom	Fuel valve	opens 7° B.B.C.	closes	35° A.B.C.
	Air inlet valve	,, 27° B.B.C.	,,	26° A.T.C.
	Exhaust valve	,, 38° B.T.C.	,,	22° A.B.C.
	Air starting valve	,, 17° A.B.C.	,,	134° A.B.C.

Crank Sequence.

Cranks Nos. 1 and 6 on top centre.

Cranks Nos. 3 and 4 at 120° and leading.

Cranks Nos. 2 and 5 at 120° and trailing.

Running Data of Twin Screw 8-Cylinder D.A. 4-Cycle Engine.

Diameter of cylinders - - - = 840 mm.
Stroke - - - - - = 1500 mm.
Revolutions - - - - = 110.
Speed - - - - - = 16·3 knots.
Slip - - - - - = 15·5 per cent.

STARBOARD ENGINE.

M.I.P. top = 6·43 K/square cm. (mean).
M.I.P. bottom = 5·62 K/square cm. (mean).
I.H.P. top = 5206 (for 8 cylinders).
I.H.P. bottom = 3840 (for 8 cylinders).
Fuel per I.H.P. hour = ·304.
Specific gravity of fuel = ·86.
Flash point = 190° F.
Exhaust temperature top = 788°.
Exhaust temperature bottom = 702° F.
Jacket cooling water outlet temperature = 135°.
Piston cooling water outlet temperature = 155°.

Lubricating Oil Consumption Referred to Fuel Consumption.

(From Actual Practice.)

For reasons stated elsewhere the lubricating oil consumption is usually higher for 2-cycle engines than for those of the 4-cycle type, and the quantity used per day shows a considerable variation in different builds of engines. Referred to fuel consumption the lubricating oil used, say, per day appears to be less for engines of high power than for those of low power. The following notes refer to 4-cycle engines only :—

Example A (S.A. Engine).

Fuel consumption = 7·55 tons per 24 hours.
Lubricating oil consumption = 14 gals. ,,
Assume specific gravity of lubricating oil to be, say, ·92.

Then, lbs. of lubricating oil = 14 × 9·2 = 128·8 per 24 hours.
,, ,, fuel = 7·55 × 2240 = 16912 ,,
So that lubricating oil referred to fuel oil
$$= \frac{128·8 \times 100}{16912} = ·76 \,°/_\circ$$

which means that the lubricating oil consumption = ·76 of 1 °/₀ fuel oil.

Again, referring to the lubricating oil used per 1000 B.H.P. per hour, the B.H.P. being 1886.

Then, $\dfrac{128·8}{24 \times 1·886} = 2·84$ lbs. per hour per 1000 B.H.P.

Note.—9·2 × 10 = 9·2 lbs. per gal.
,, 1886 ÷ 1000 = 1·886.

Example B (S.A. Engine).

Fuel consumption	$= 7.45$ tons per 24 hours.
Lubricating oil consumption	$= 104.6$ lbs. ,,
I.H.P. $= 2500$.	B.H.P. $= 1850$.

Lubricating oil referred to fuel oil

$$= \frac{104.6 \times 100}{7.45 \times 2240} = .62 \, \%$$

Referred to 1000 I.H.P. per hour, $2500 \div 1000 = 2.5$.

Then, $\dfrac{104.6}{24 \times 2.5} = 1.74$ lbs. per 1000 I.H.P. per hour.

Referred to B.H.P. per hour, $1850 \div 1000 = 1.85$.

Then, $\dfrac{104.6}{24 \times 1.85} = 2.35$ lbs. per 1000 B.H.P. per hour.
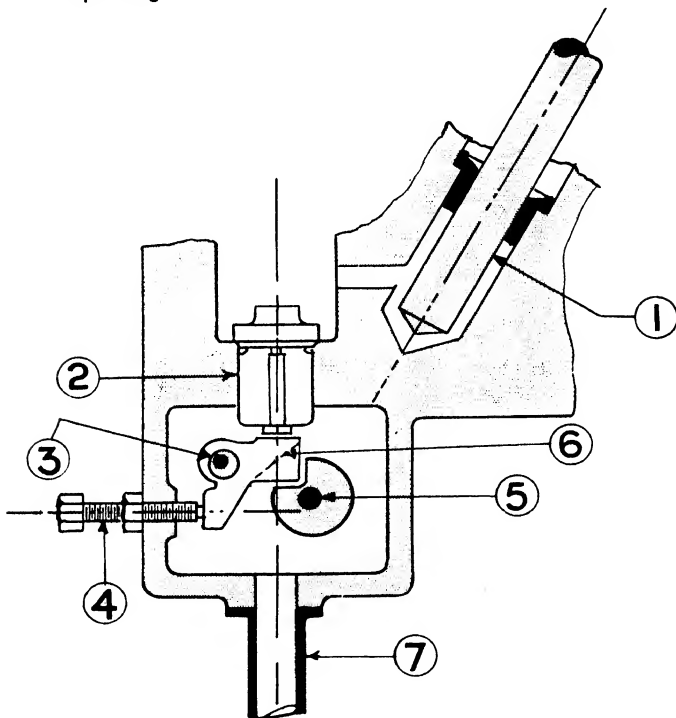
No. 489.—Harland & Wolff Fuel Pump Suction
Valve Control.

1, Fuel pump plunger.
2, Suction valve of pump.
3, Eccentric shaft and bell crank adjustment for valve
    lift (reciprocating motion).
4, Hand adjustment screw for suction valve lift.
5, Governor trip shaft gear.
6, In, say, an 8-cylinder engine the dotted line shows how
    the trip cam of *one* of the eight cylinders is not cut
    out by governor action when racing occurs. This is
    to ensure that the engine will not bring up and
    stop altogether.
7, Fuel inlet from settling tank to fuel pump chest.

SECTION X

GENERAL NOTES AND SKETCHES

BÜCHI SYSTEM OF EXHAUST TURBO-CHARGING

This system is characterised by slightly compressed air being introduced into the cylinders. The engine, therefore, does not draw in air from the atmosphere like an ordinary 4-cycle Diesel engine, as the air introduced to it is first of all compressed by a turbo-blower. At the beginning of compression, there is a greater weight of air present in the cylinder, and a correspondingly greater amount of fuel can be consumed without any increase in the temperature of combustion.
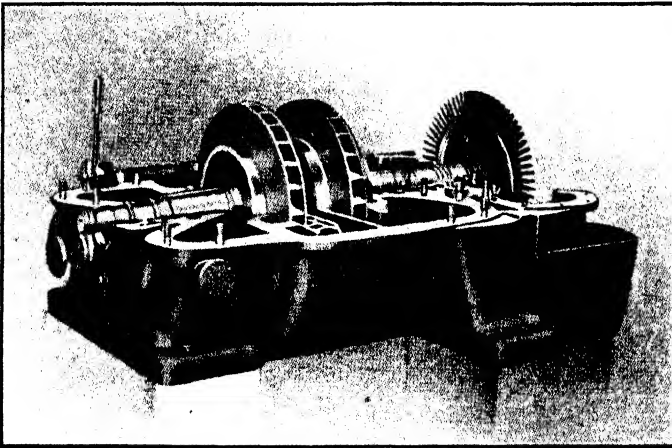
No. 490.—Exhaust Gas Turbine and Blower, with Cover
Removed.*

The single impulse wheel of the turbine is shown on right, and the two-stage impeller of the supercharge blower on left.

The turbo-blower, which has only a few stages (usually two) varying in number according to the size of the engine and the amount of air required, is driven by means of a turbine, which in turn is driven by the exhaust gases from the working cylinders. Consequently, no outside means, such as an auxiliary Diesel engine or an electric motor, is required to drive the turbo-blower. The charging plant is self-contained, since the exhaust gases from the working cylinders are available for utilisation when the main engine is started up.

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As already mentioned, a correspondingly greater amount of fuel can be burned owing to the greater weight of air present in the cylinder, whilst the same temperature of combustion is maintained ; therefore, the indicator diagrams given by the cylinder are larger, *i.e.*, the output of the engine is considerably increased.   The method
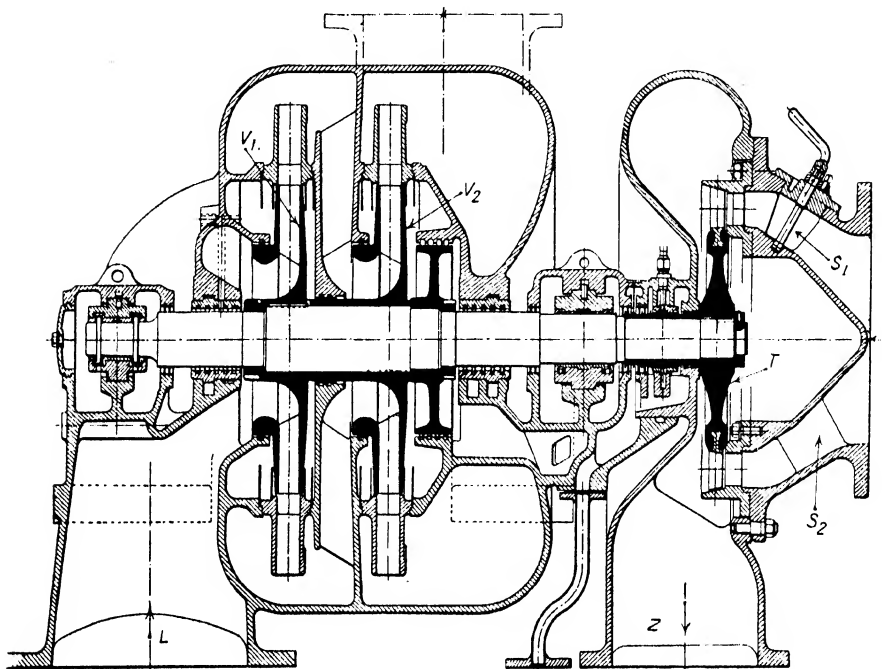
No. 491.—Exhaust Gas Turbine and Two-Stage
Supercharge Blower.*

S$_1$, S$_2$, Exhaust gas inlet to turbine wheel.
V$_2$, V$_1$, Two-stage air impeller of blower.
   L, Intake of suction air to blower.
   T, Impulse turbine wheel.
   Z, Exhaust gas outlet from turbine to atmosphere.

The turbine blading is constructed of chrome-nickel steel, a single-impulse wheel and nozzle plates being fitted.

of working adopted and the provision of a special method of scaveng-ing the working cylinders, make it possible to attain an augmentation of output that corresponds to the ratio of the absolute charging pressure to the atmospheric pressure. If the ratio of compression

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in the working cylinders is somewhat lowered, in Diesel engines as hitherto built and with a charging air pressure of about 4·2 lbs. gauge, the same final pressures can be attained without any extra stresses being put on the running gear or on the bearings. Therefore, keeping to the same speed for the engine and the same exhaust gas temperatures, there results an increase in output of about 50 per cent., i.e., the engine can carry continuously 50 per cent. more load than an ordinary Diesel engine of the same dimensions. If the load on the engine rises above normal, the speed of the turbine will also rise, in consequence of the greater quantity of exhaust gases, therefore more air will be drawn in by the charging air blower and compressed; and with such an engine, whilst still keeping to the same exhaust gas temperatures and still having perfect combustion, higher overload can be carried than in Diesel engines as hitherto built. Another factor which contributes to this result is the scavenging effect, which increases with increase in load. The engine is therefore much more elastic than the ordinary Diesel engine to which the same quantity of air is introduced, whatever be the load on the engine.

Fuel Consumption.

The fuel consumption in turbo-charged engines is on all loads lower than in ordinary 4-cycle engines, about 5 per cent. less on normal load and less still on partial loads.

Heat Stresses in Cylinders, Pistons, and Valves.

Particular attention is called to the fact that the heat stresses in the cylinders, the pistons, and the valves, are of the same order as in the usual type of 4-cycle Diesel engine, since with the 50 per cent. increased output only about the same quantity of heat has to be carried away in the cooling water as in an ordinary Diesel engine working with a far lower normal load. This advantage is to be attributed mainly to the special method of scavenging already mentioned.

Attention when Running.

Pay particular attention to the working of the plant, since the gas turbine and the charging air blower require no special attention. The bearings of these machines are lubricated from the forced lubricating system of the engine.

D.E.—50

Starting.

The engine is also started like a Diesel engine. During this operation it is advantageous to draw in air from the atmosphere and exhaust to the atmosphere; for this purpose two simple gate valves in the air and exhaust pipes have to be operated. As soon as the engine is running, these valves are closed and the exhaust gases then pass into the turbine which starts up and drives the charging air compressor at a certain speed which depends on the load on the engine, thus developing a certain charging air pressure. The exhaust turbine can also be fitted with an automatic governing device, in order to make the engine capable of coping with sudden changes of load.

Construction.

The Diesel engine adopted does not differ in any respect from the well-proved type of Diesel engine. Only the piping for admitting air and for carrying away the exhaust gas is altered to suit the new engine, and the admission and exhaust valve spindles are fitted with packing springs working in cooled guides, so that the compressed air and the exhaust gases are prevented from escaping past them.

Cooling Water and Lubricating Oil.

Because there is less heat to be carried away per unit of power, the quantity of cooling water required is less. The lubricating oil consumption is also less, since the cylinders, bearing surfaces, etc., requiring lubrication are smaller.

Silent Exhaust.

The noise of the exhaust is completely silenced by the turbine, so that any annoyance from this cause is eliminated.

The air drawn from the engine-room enters at the centre of the first impeller of the blower, is compressed, and discharges at the circumference to enter the centre of the second impeller, being finally discharged from the circumference of same to the piping of the cylinder on inlet valves at a pressure of from 2 to 3 lbs. gauge. By-pass valves are provided to allow of the exhaust being led direct to the silencer without passing through the turbine, in case of breakdown.

By-pass valves are also fitted to permit of the engine drawing in suction air direct to the cylinder valves with the supercharge blower cut-out.

Trial Results.

M.V. " Raby Castle "

Results of Trials before and after Conversion to the Büchi System of Exhaust Turbo-Charging

Description of Trial.	Original Official Full-Power Shop Trial.	Original Official Full-Power Sea Trial.	After Conversion.	
			At Original Full Power.	At New Full Power.
Date - - - - - -	30/12/24	7/4/25	26/9/28	26/9/28
Draught - - - - -	...	13 ft. 1½ in.	13 ft. 9 in.	
Displacement - - - -	...	5600 tons	5900 tons.	
Revolutions per minute - -	95·1	92·5	86·24	96·9
Maximum combustion pressures (mean of all cylinders) - -	569 lbs.	567 lbs.	542 lbs.	572 lbs.
Pressure in exhaust main - -	...	...	1·93 lbs.	3·72 lbs.
Pressure in air main - - -	...	...	2·00 lbs.	4·49 lbs.
Mean speed - - - -	...	11·9 kts.	11·934 kts.	13·334 kts.
Mean exhaust temperature (in water-cooled pipe) - -	643·5° F.	587·3° F.	Not fitted.	
Ditto in uncooled pipe (3 in. lagging) - - - -	Not fitted.		621° F.	720° F.
Blast air pressure - - -	975 lbs.	1000 lbs.	900 lbs.	950 lbs.
Sea temperature - - -	43·5° F.	Not recorded.	57° F.	57° F.
Cylinder cooling-water outlet -	84·3° F.	Not recorded.	77° F.	83° F.
Piston cooling-water outlet -	79·9° F.	Not recorded.	85° F.	95° F.
Temperature lubricating oil from guides - - - - -	Not recorded.		80° F.	83° F.
Speed of turbo-blower - -	Not fitted.		2850 r.p.m.	4037 r.p.m.

M.V. " Lochmonar "

Length - - - - - - - -	485 ft. 8 in.
Beam - - - - - - - -	62 ft. 3 in.
Depth, moulded - - - - -	38 ft. 9 in.
Freeboard amidships - - - - -	9 ft. 7½ in.
Draught, loaded - - - - -	29 ft. 6½ in.
Gross register - - - - - -	9412 tons.
Engine output, maximum (unsupercharged) -	6000 I.H.P.
Number of cylinders, each engine - - -	8.
Diameter - - - - - - -	740 mm.
Stroke - - - - - - - -	1150 mm.
Revolutions - - - - - -	115 per min.
Speed (unsupercharged), loaded - - -	12 knots.
Speed (supercharged), loaded - - - -	13 knots.

NOTE.—On the basis that, approximately, the power varies directly with the cube of the speed :

Then, $\dfrac{6000 \times 13^3}{12^3} = 7628$ I.H.P. with supercharge.

Increase of power $= \dfrac{7628 - 6000}{6000} \times 100 = 27$ per cent.

Both vessels referred to were converted to the Büchi supercharge system, and the comparative results are shown before and after conversion.

Referring to the " Raby Castle," it will be noticed that the firing pressure is less when supercharged, and when developing the same power as without supercharge.

The exhaust gases enter the turbine at, say, 700° F., and a pressure ranging from 2 to $3\frac{1}{2}$ lbs. gauge, whereas the compressed air is discharged from the second-stage impeller wheel to the suction valve piping at a pressure of from 3 to $4\frac{1}{2}$ lbs. gauge.

The turbine is designed to run at a revolution speed of from 3000 to 4000 per min.
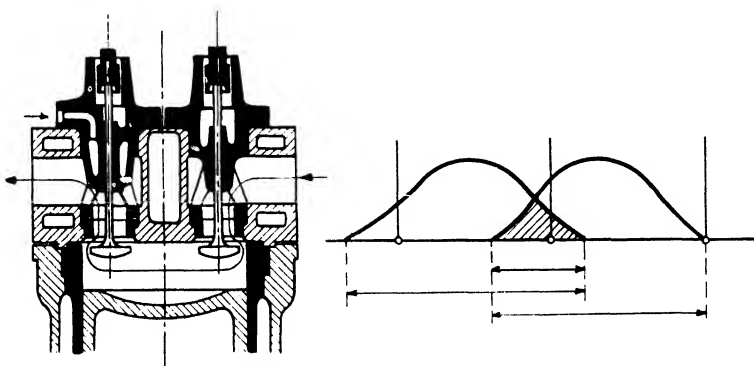
Exhaust and Scavenge Air Valves at Overlap Period of Stroke. *

Both valves are open at the same time for a period covering about 100° of the crank circle. The arrows show the supercharge air entering the cylinder (right) and forcing out the exhaust gases (left), which results in the efficient evacuation of the latter. The two diagrams on right show the air inlet and exhaust strokes of the cycle with the overlap period shaded.

To permit of efficient scavenging, the exhaust valves and air inlet valves are open for a longer period than is usual in ordinary practice, the overlap extending from 60° to 100° or more, of the crank circle.

To retain the heat contained in the exhaust gases for use in the turbine, the exhaust pipes from the cylinders are left uncooled and are well lagged. When working under overload conditions, the maximum firing pressure remains much as before, but as the fuel valve closing position seems later on the stroke, the M.I.P. is increased. Therefore, taking into account increase of revolution speed, the mean turning moment on the shaft is only slightly increased.

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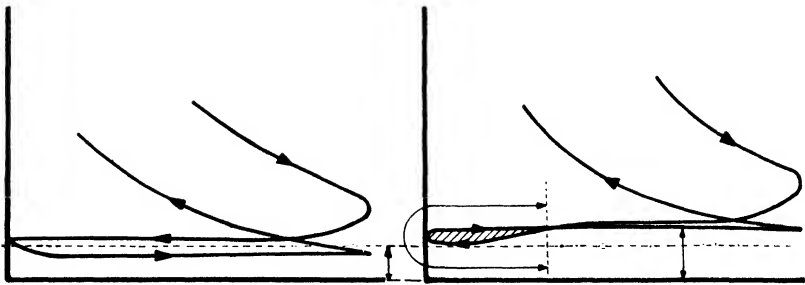
Low Spring Indicator Diagrams.*

The diagram on left represents ordinary 4-cycle engine practice, with the inlet air suction pressure below atmospheric pressure (about $1\frac{1}{2}$ lbs.). The diagram on right shows the effects obtained by supercharge air. It will be noted that the exhaust gas pressure is higher than before, and the air inlet pressure is a few pounds above atmospheric pressure. The curved line with arrows indicates the position of the stroke at which the exhaust gas pressure suddenly drops owing to the accelerated speed of the exhaust gases produced by the supercharge air admission.

* Reproduced by courtesy of Messrs Brown, Boverie & Co., Switzerland.
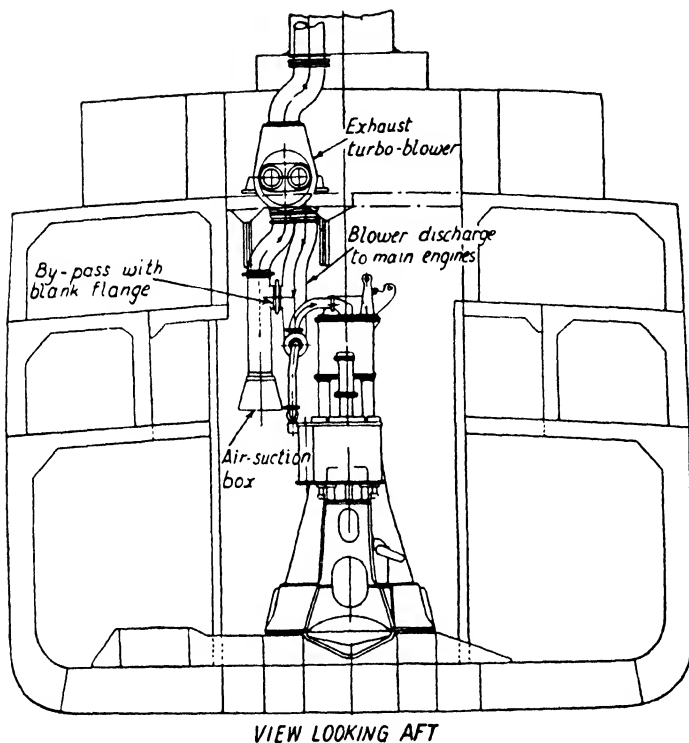
Büchi System of Supercharge. *

If the blank flange shown is removed, the cylinders will then draw in air direct from the atmosphere, without supercharge.

* Reproduced by courtesy of *The Shipbuilder*.
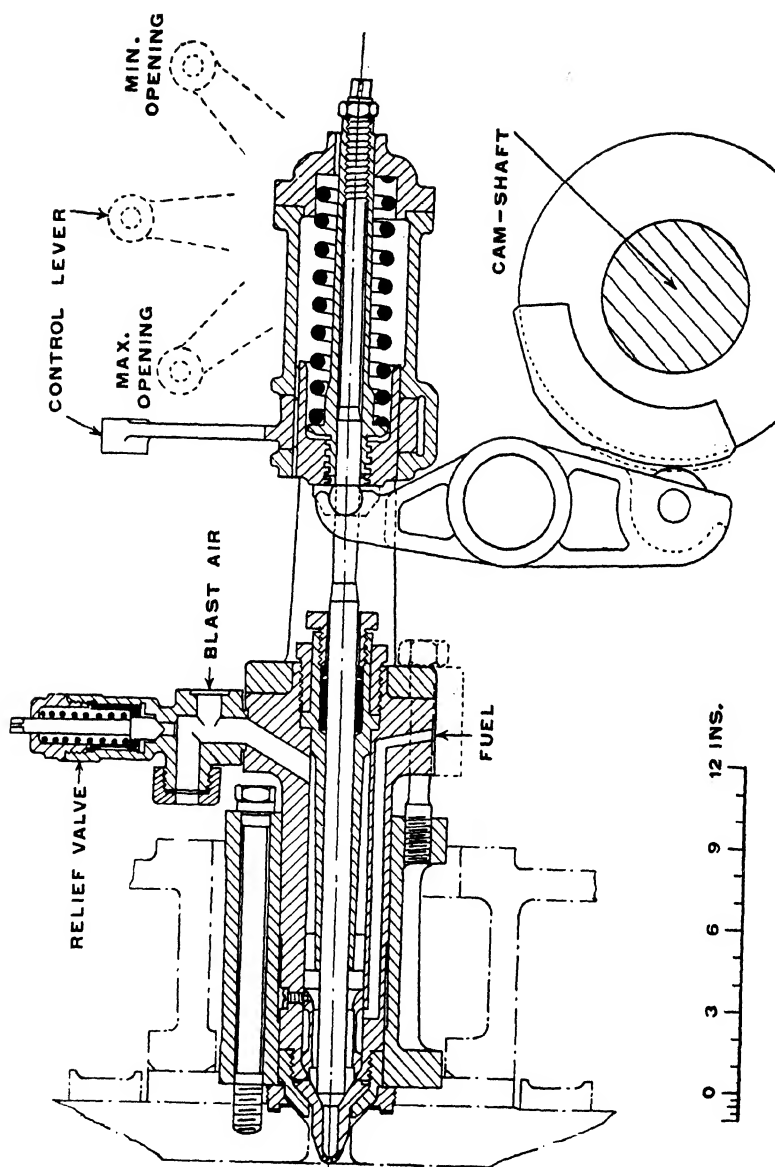
No. 492.—Fuel Valve.*

(Palmer-Camellaird-Fullagar Opposed Piston, 2-Cycle, 6-Cylinder, Blast
Air Injection Engine.)

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One fuel valve is fitted to each cylinder at the front of the engine on the horizontal centre line of the spherically shaped combustion space. The valve is of the needle type (opens away from the cylinder), and is returned to its seat by means of the spring in the upper casing. The timing and period of opening are controlled by the fuel valve hand wheel as follows :—

The sleeve on the outer end of the fuel valve needle is screwed externally, and engages with a nut which is loosely keyed to the control lever : movement of the lever advances the nut either to left or right and accordingly either advances or retards the fuel timing by alteration of the roller position on the valve actuating lever with respect to the cam. All the control levers operate in unison with the hand wheel. The adjustment described refers to alteration of the fuel valve timing with engine running, but for permanent adjustment the sleeve is screwed internally and meshes with the screwed end of the valve spindle, the method of carrying out the operation being similar to that already described. A bursting diaphragm and a relief valve are incorporated in the fuel valve casing, and suitable valves are fitted to allow of cutting off the fuel and blast air from the cylinder in case of breakdown.

It will be noticed that the fuel valve end is closed in by a cap provided with a number of small openings, these acting as atomisers to the fuel delivery into the cylinder.

AIR INLET

WATER SPACE

RELIEF-VALVE

0   2   4   6   8   10 INS.
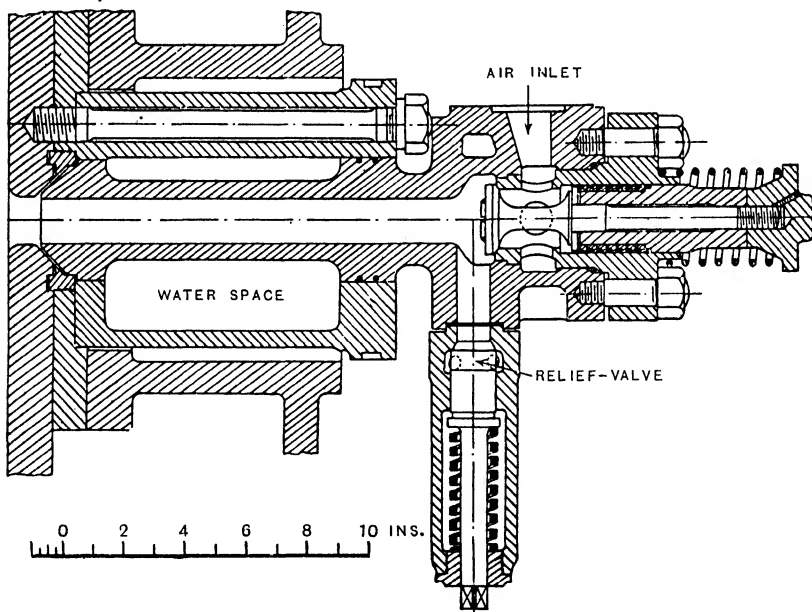
No. 493.—Starting Air Valve.*
(Palmer-Camellaird-Fullagar Opposed Piston, 2-Cycle, 6-Cylinder,
Blast Air Injection Engine.)

Each cylinder is fitted with a starting air valve in which is incorporated a relief valve.

The starting air pressure is about 600 lbs., and the cam-operated valve remains open for 82° A.T.C. of the lower piston of the pair.

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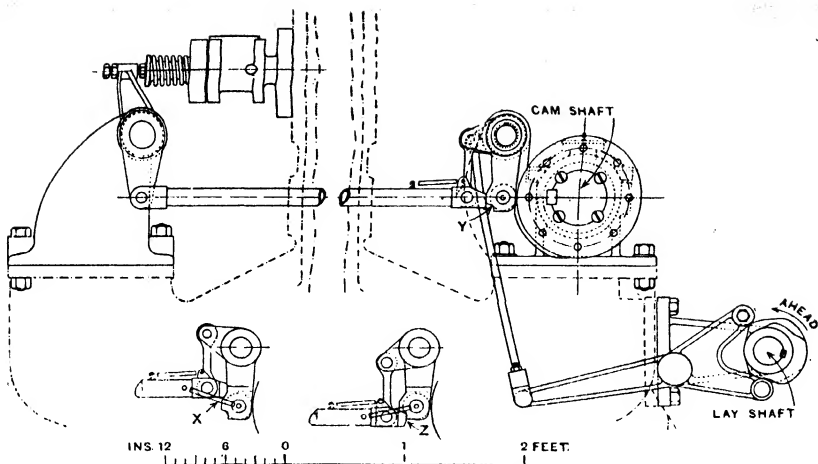
No. 494.—Starting Air Valve Actuating Gear.*

(Palmer-Camellaird-Fullagar Opposed Piston, 2-Cycle, 6-Cylinder,
Blast Air Injection Engine.)

X, Position of gear with engines stopped.
Y,　　,,　　　,,　　　engine receiving starting air.
Z,　　,,　　　,,　　　,,　　　,,　　fuel.

The cylinders are cut off from starting air and put on to fuel in groups of two at a time, and when all the cylinders are taking fuel, the whole engine is cut out, automatically, from the starting air system.
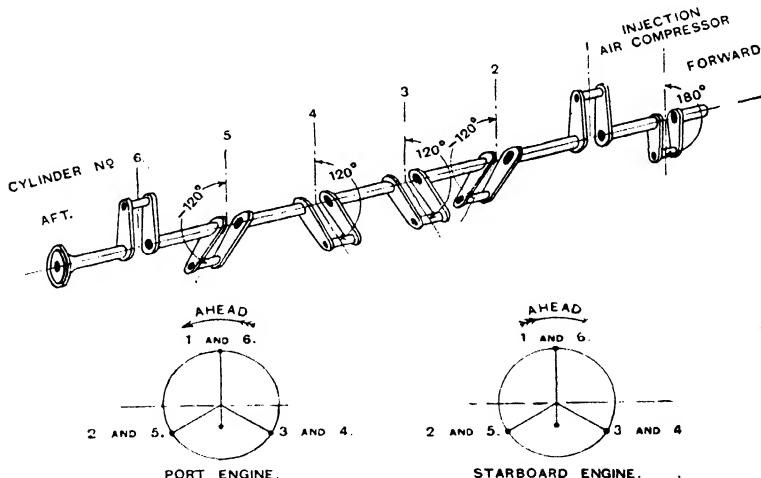
No. 495.—Crankshaft Angles and Firing Sequence.*

(Richardsons-Beardmore-Tosi Director Valve Type, 6-Cylinder, 4-Cycle,
Single-Acting, Blast Air Injection Engine.)

Firing sequence (ahead), 1, 4, 2, 6, 3, 5.
　　　,,　　　,,　　(astern), 1, 5, 3, 6, 2, 4.

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12 INCHES

10

8

6

4

2

0

AIR INLET,
(SHOWN DOTTED)

FUEL INLET
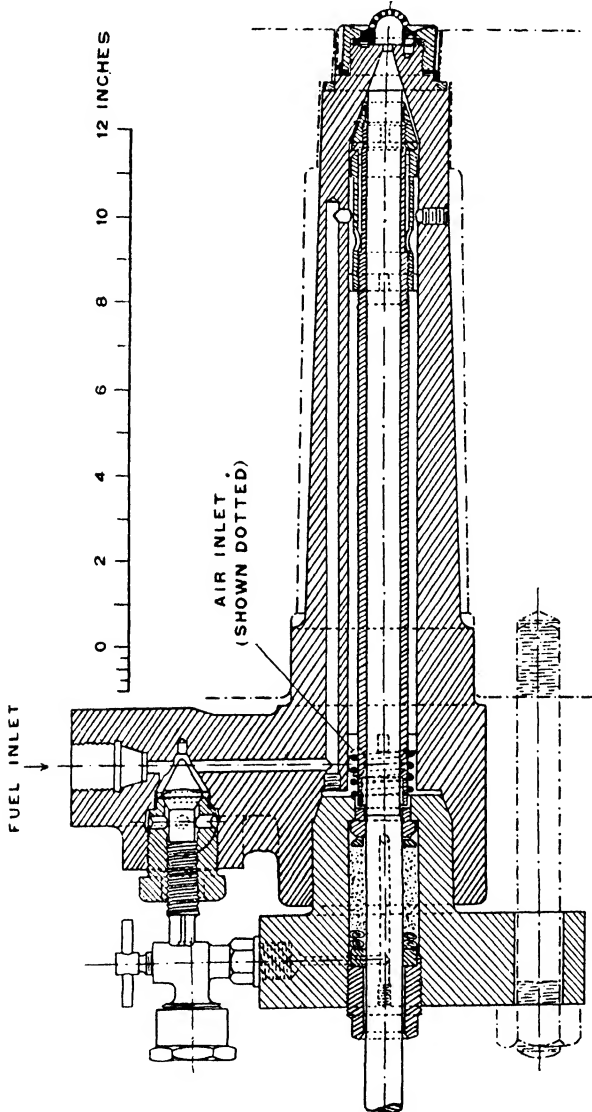
No. 496.—Fuel Injection Valve (Needle Type).*

(M.V. " Cape York," Hawthorn-Leslie-Werkspoor Engine, 4-Cycle,
Single-Acting, with Blast Air Injection.)

The outlet end of the valve is provided with a close-ended cap which is
perforated with a number of small diameter holes through which the fuel
is atomised during injection.   The cap is similar to that fitted on fuel injection
valves of the airless or solid injection type.   The valve opens 7·5° B.T.C.

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WATER SPACE

AIR INLET

WATER SPACE

12 INCHES
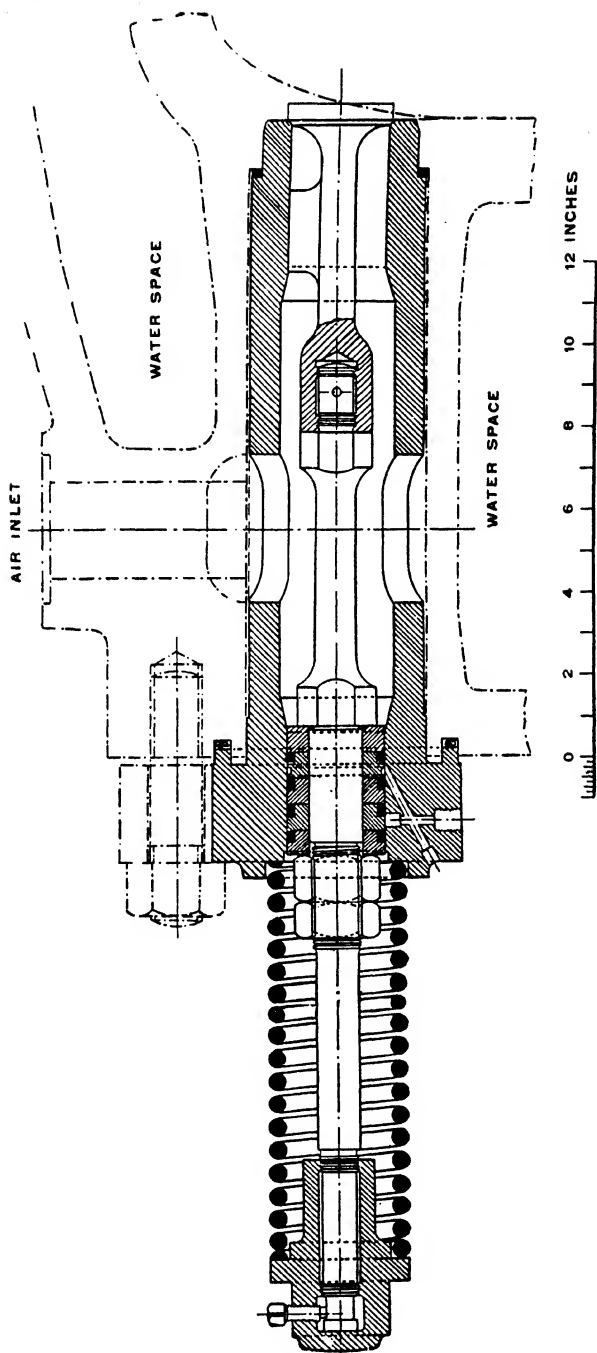
No. 497.—Cylinder Starting Air Valve.*

(Hawthorn-Leslie-Werkspoor Engine.)

Movement of the manœuvring hand wheel of one quarter turn puts all the starting air valves into communication with the air tanks, and all the cam rollers on the starting air bell crank levers into contact with their cams, and the engine will commence to run on "6 cylinders on air" position. A further movement of the hand wheel through another quarter turn changes to "3 cylinders on fuel" and "3 cylinders on air," and a further quarter turn of the wheel puts all "6 cylinders on fuel." Starting air remaining open for 128·5° A.T.C. (6-cylinder, 4-cycle engine).

Starting air pressure is 250 lbs., the valves remaining open for 128·5° A.T.C. (6-cylinder, 4-cycle engine).

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CAMSHAFT

PUMP BORE $1\frac{1}{8}''$

STROKE $3''$

DISCHARGE

VENT

SUCTION

ISOLATING VALVE

0   5   10   15   20 INS
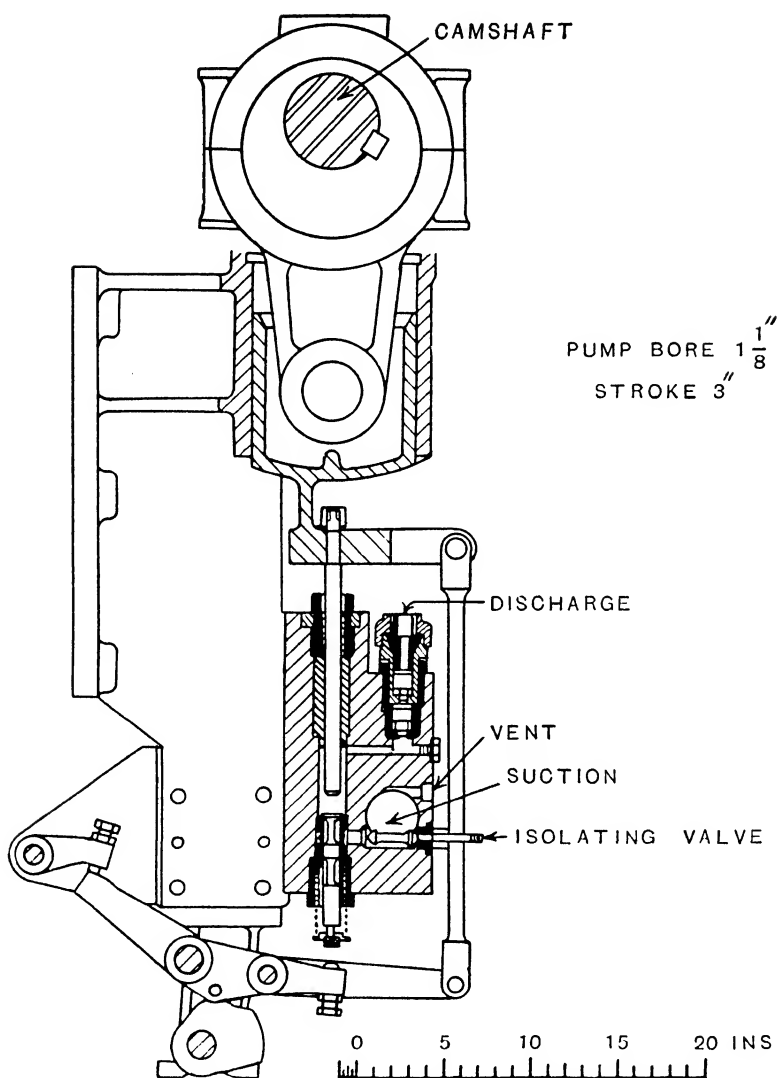
No. 498.—Fuel Pump.*

(M.V. "British Aviator," Palmer-Camellaird-Fullagar Opposed Piston, 2-Cycle, 6-Cylinder, Single-Acting Blast Air Injection Engine.)

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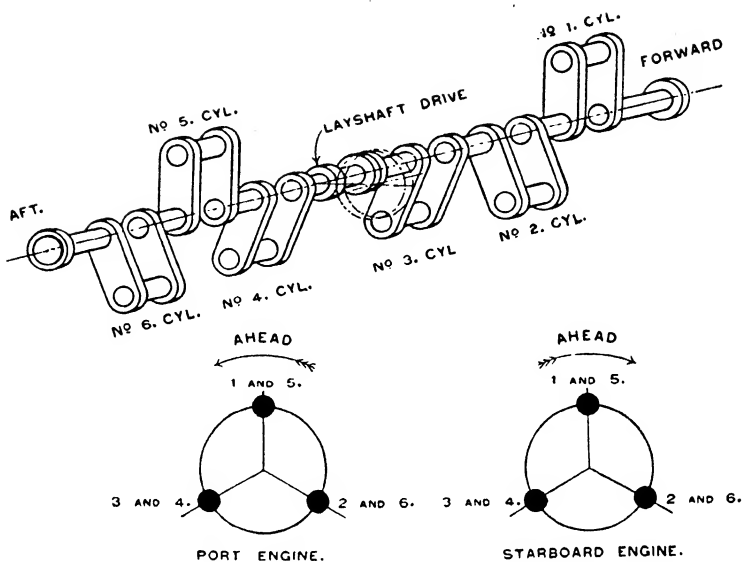
No. 499.—Crankshaft Angles and Firing Sequences.*

(M.V. "Cape York," Hawthorn-Leslie-Werkspoor Engine, 4-Cycle,
with Blast Air Injection.)

Firing Sequence.

Engine.				Direction.	Cylinder.
Port	-	-	-	Ahead	1, 4, 2, 5, 3, 6
Starboard	-	-	-	Astern	...
Port	-	-	-	Astern	1, 6, 3, 5, 2, 4
Starboard	-	-	-	Ahead	...
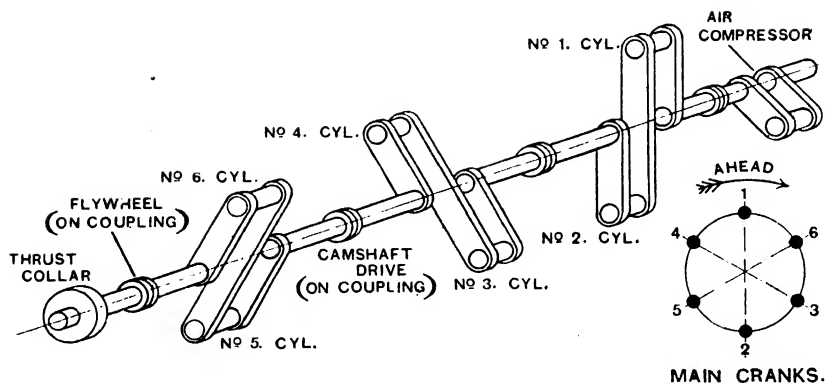
No. 500.—Crankshaft Angles and Firing Sequence.*

(M.V. " British Aviator," Palmer-Camellaird-Fullagar Opposed Piston, 2-Cycle, 6-Cylinder, Single-Acting Blast Injection Engine.)

Firing sequence (ahead), 1, 4, 5, 2, 3, 6.

,,   ,,   (astern), 1, 6, 3, 2, 5, 4.
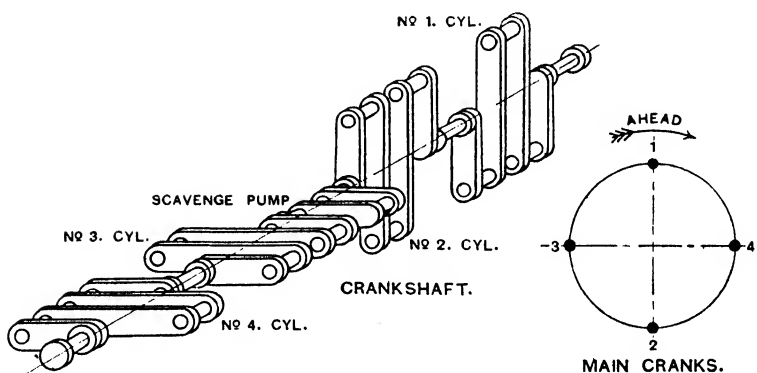
No. 501.—Crankshaft Angles and Firing Sequence.*

(M.V. " Pacific Trader," Doxford, 4-Cylinder, Opposed Piston, 2-Cycle, Airless Injection Engine.)

Firing sequence (ahead), 1, 3, 2, 4.

,,   ,,   (astern), 1, 4, 2, 3.

* Reprinted by courtesy of the Council of the Institution of Mechanical Engineers.
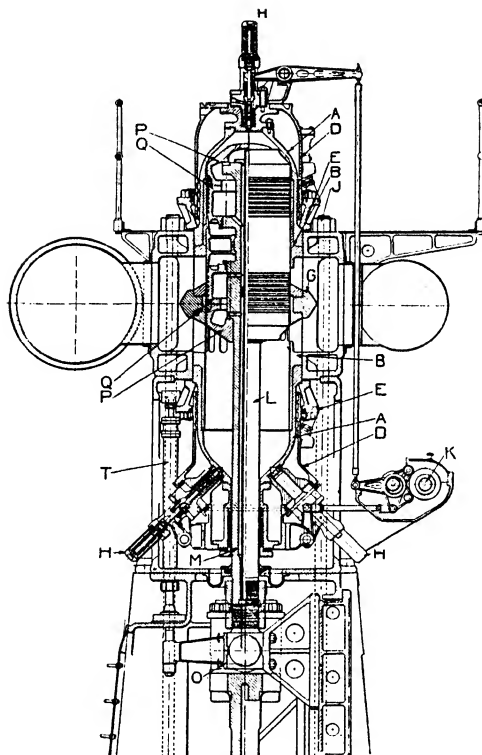
No. 502.—Worthington Type 2-Cycle Double-Acting Engine.

Cylinder diameter = 27 in.
Piston stroke = 40 in.
Piston speed = 660 ft. per min.
Revolutions = 96.
M.I.P. = 79·5 lbs. $\boxed{''}$.
Mechanical efficiency = 72 per cent.

A, A, Upper and lower steel cylinders into which the liners B are lightly pressed and secured by bolts.

B, B, Upper and lower cylinder liners.

D, Light cast-iron cover of cylinder water jackets.

E, Clamping rings with bolts which hold in position the cylinder block, cylinder and liners, with expansion allowance.

G, Cast-iron division ring to receive flange of each liner top and bottom.

L, Piston rod with axial hole M for water cooling.

H, H, Fuel valves, one at top, two at bottom.

P, Piston heads of chrome steel.

Q, Cast-iron piston ring boxes.

M, Axial hole in piston rod for water cooling.

T, Telescope water cooling pipe.

K, Camshaft.

J, Vertical bolts (4) which extend from cylinder top to bedplate below.
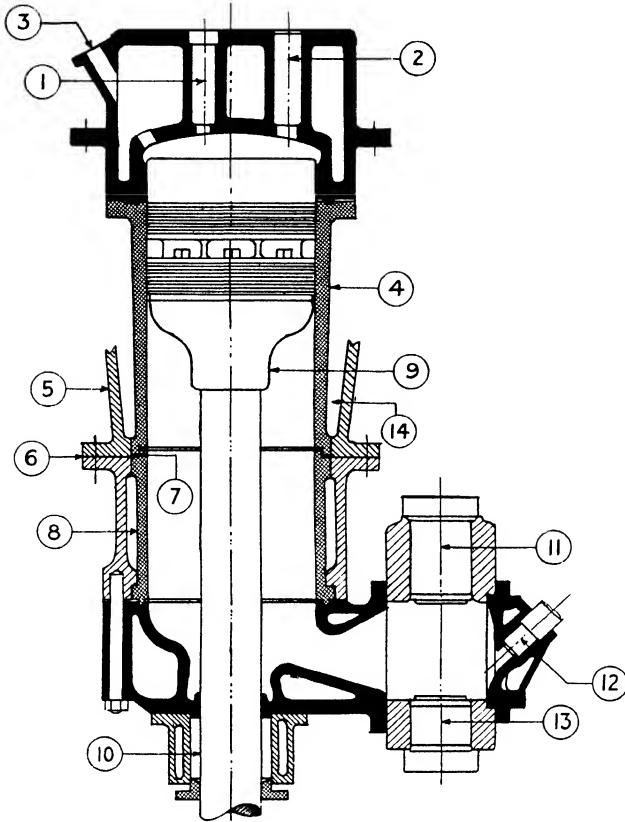
**No. 503.—Double-Acting 4-Cycle "N.E. Marine"
Werkspoor Engine.**

(Sketch suitable for Examination purposes.)

1, Fuel valve.
2, Air suction valve.
3, Relief valve.
   (Exhaust valve in position behind the valves named.)
4, Cylinder liner (upper section).
5, Cylinder casting.
6, Joint which if broken admits of examination or withdrawal of the piston.
7, Liner joint of copper.
8, Cylinder liner (lower section).
9, Enlarged diameter of piston rod which enters stuffing box and wire draws the gases of combustion.
10, Piston rod stuffing box fitted with inspring and outspring Ramsbottom type rings and water cooled.
11, Exhaust valve.
12, Fuel valve.
13, Air inlet valve.
14, Cylinder cooling water jacket space.

The engine is arranged with starting air on the top side of the pistons only.

The bottom exhaust valves are held open at all positions of the starting shaft, the bottom air inlet valves remaining closed except in the final stage of manœuvring which allows all of the cylinders to operate double acting. In starting on the top side first the exhaust gases from the top pass to the bottom and raise the temperature sufficiently to permit of ignition when the fuel is injected; the engine then starts up single acting, and afterwards merges into the double-acting system as described.
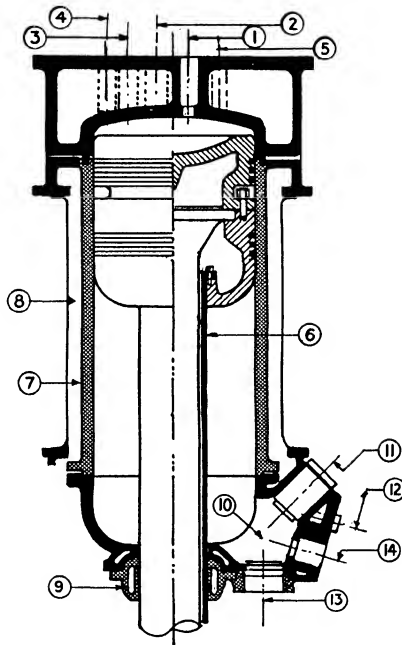
No. 504.—Double-Acting 4-Cycle Engine Cylinder.

(Harland & Wolff B. & W.)

(Sketch suitable for Examination purposes.)

1, Top fuel valve.
2, Top exhaust valve.
3, Top air suction valve.
4, Top air starting valve.
5, Top relief valve.
6, Piston rod liner.
7, Cylinder liner.
8, Cooling water jacket space.

9, Water-cooled gas-tight gland fitted with rings.
10, Bottom combustion pocket.
11, Bottom air suction valve.
12, Bottom fuel valve.
13, Bottom exhaust valve.
14, Bottom air starting valve.

The combustion pocket forms the bottom clearance volume.

D.E.—5 I
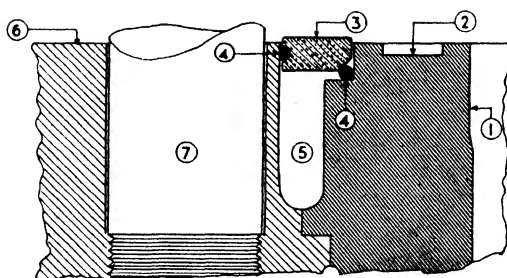
No. 505.—Jointing for Cylinder Jacket and Liner.

(H. & W. Engines.)

1, Inside bore of liner.

2, Ground face to form joint with spigot of cylinder head.

3, Loose brass ring.

4, 4, Rubber jointing rings.

5, Cooling water jacket space at top of liner.

6, Cylinder metal.

7, Cylinder head stud.

The loose brass ring and pair of rubber rings shown form a self-adjusting joint when the cylinder head spigot is bearing hard on the liner groove, and permits of cooling at a position where the temperature is at a maximum.
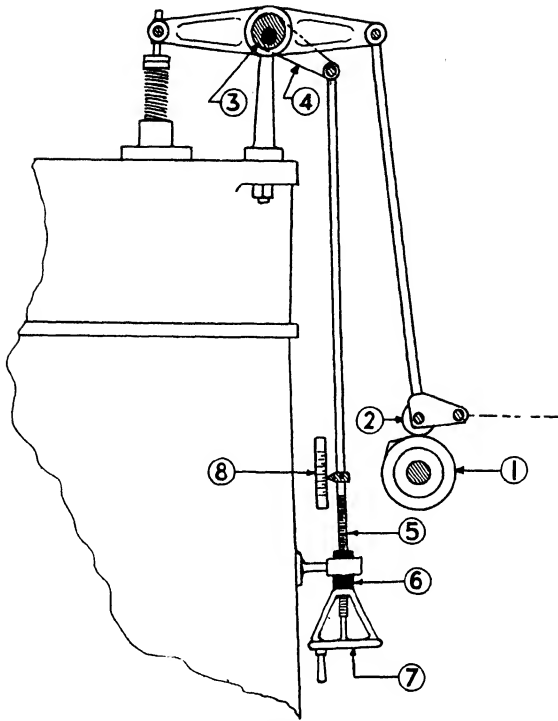
No. 506.—Fuel Valve Lift Control.
(H. & W Engines.)

1, Fuel valve cam.
2, Fuel valve cam roller.
3, Eccentric on lever shaft.
4, Lever connected to eccentric.
5, Screwed rod.
6, Nut of hand wheel.
7, Hand wheel control of valve lift.
8, Index.

When running under conditions of low revolution speed and low power, the lift of the fuel valve can be reduced by turning the hand wheel so that the screwed spindle (5) travels upwards and operating lever (4) moves round the eccentric on which the fuel valve lever is mounted, and in this manner increases the cam roller (2) clearance. The fuel valve will now open later and close earlier, and reduce wastage of blast air and the cooling effect of same. It should be remembered that the fuel pump measures the quantity of fuel supplied to the cylinder, whereas the cylinder fuel valve times the admission of the fuel; as, therefore, at low loads less fuel is being supplied, less blast air will also be sufficient.
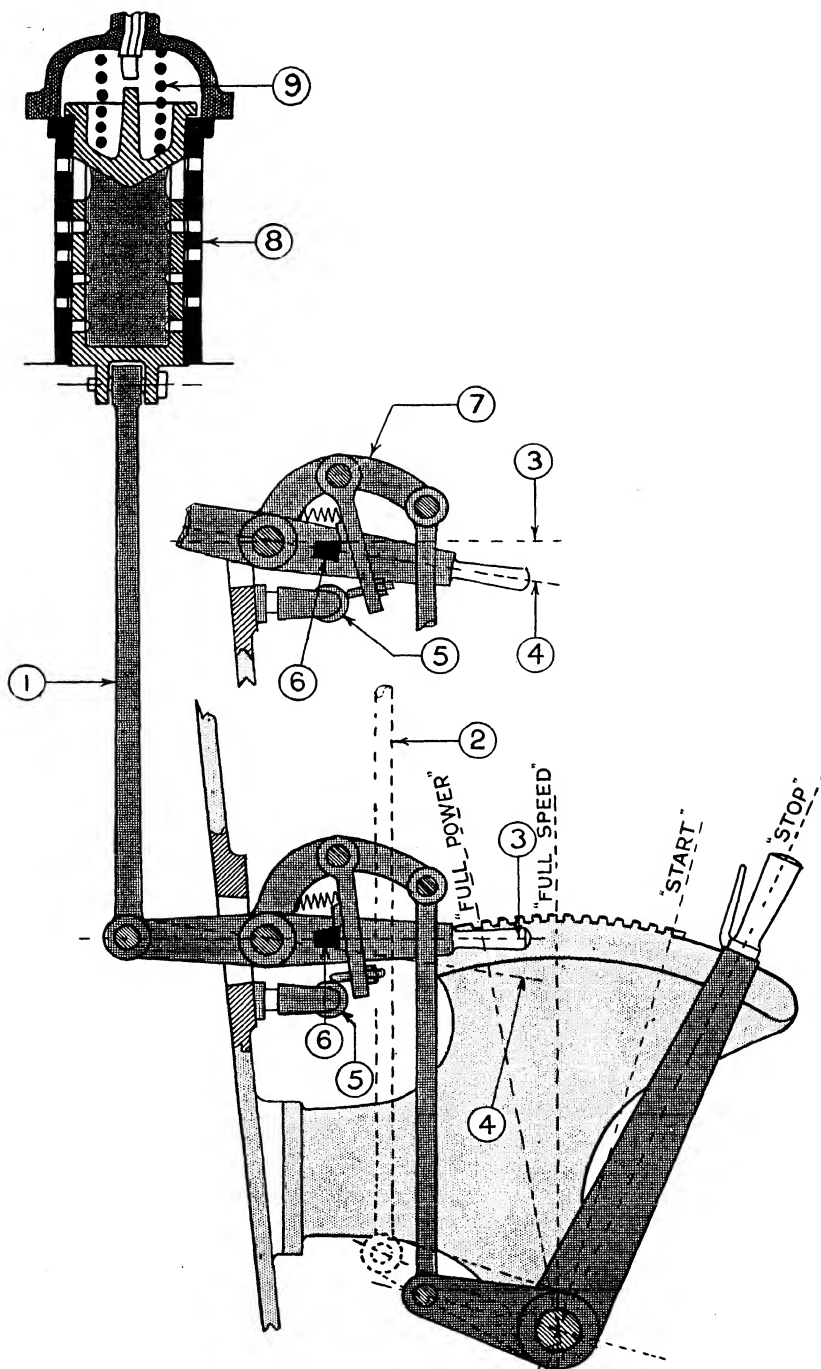
Starting Air and Fuel Control (H. & W. Engine).

No. 507.—Operation of Starting Air Slide.

(H. & W. Engine.)

The lower view shows the air slide in closed position, and the small upper view the slide in " open " position, with the bent lever and gear just on the point of being released to close the valve.

1, Rod of air slide.

2, Rod connecting to eccentric gear of fuel pump suction valve tappet which is released to come into effective operation immediately the air slide closes.

3, Test handle for air slide, in " shut " position.

4, Test handle for air slide, in " open " position.

5, Trip gear roller which automatically disengages air slide and permits closing of same.

6, Trigger on lever arm which, through roller 5 and suspended loose arm on bent lever, sets free the air slide to close through the action of the upper spring in air slide chest.

7, Bent lever with loose link and catch, the latter making contact with trigger 6.

8, Air slide casing and ports.

9, Spring which forces valve down into shut-off position when trigger 6 is released.
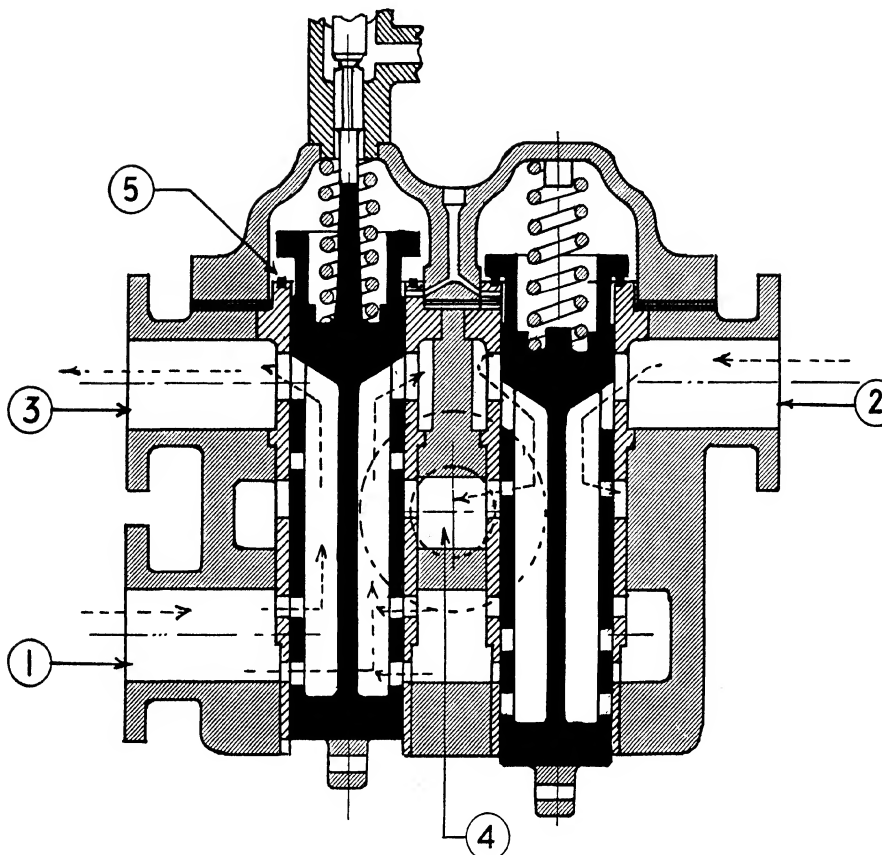
No. 508.—Twin Air Starting Slides.
(H. & W. 6-Cylinder Engine.)

Shown in position of 3 cylinders (forward) on " fuel " and 3 cylinders (aft) on " air."

1, An inlet from starting air tanks, common to all cylinders.
2, Starting air outlet to 3 forward cylinders.
3, Starting air outlet to 3 aft cylinders.
4, Exhaust air from cylinders to atmosphere, common to all cylinders.
5, Rubber ring joint.

Note.—For further index to parts, see pp. 66, 67.

In the case of 6-cylinder or 8-cylinder engines, the cylinders are arranged in two groups, and a twin set of air slides, as shown above, are usually supplied for starting purposes. In changing over from " air " to " fuel," one group of 3 cylinders (in the case of a 6-cylinder set) can first be put on fuel by the operation of one of the two air slides

by means of the starting handle, while the remaining 3 cylinders of the group are still running on air : after the short interval the other air slide is operated through the starting handle of the corresponding cylinder group, and, being automatically controlled by the overhead control valves (see p. 66), this slide cuts off the air supply to the pair. Generally, the forward group of cylinders is first put on fuel, the after group being changed over to fuel last. In actual running practice the whole of the cylinders are often switched off " air " and put on " fuel " in one movement, both starting handles being pushed over simultaneously.
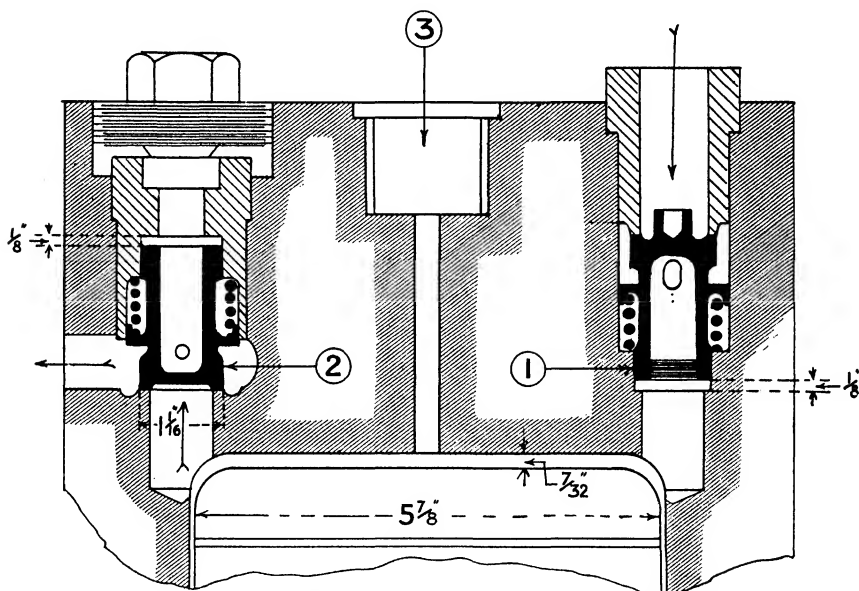
No. 509.—H.P. Stage Compressor Spring Load Valves.

1, Suction valve with lift of $\frac{1}{8}$ in. (bare).
2, Delivery valve with lift of $\frac{1}{8}$ in. (bare).
3, Recess for clearance volume adjustment device.

The piston is $5\frac{7}{8}$ in. diameter and the lineal clearance $\frac{7}{32}$ in.
The clearance volume can be increased or reduced by means of a screw adjustment in recess 3 to suit the supply of air required by conditions of running.

In modern type H. & W. compressors, dual control of the L.P. compressor air suction inlet and H.P. compressor clearance volume is arranged for, so that when the L.P. air suction opening is reduced, the H.P. clearance volume is altered proportionally and the output of air decreased in quantity and vice versa.
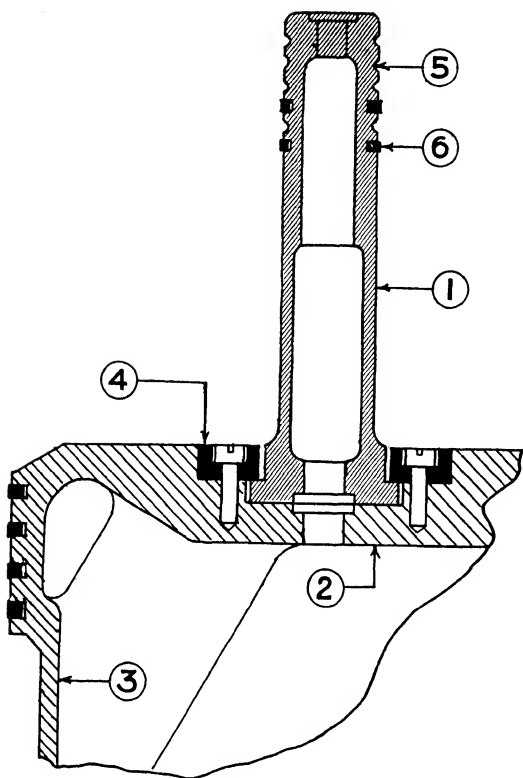
No. 510.—H.P. Compressor Piston.

1, H.P. stage compressor piston.
2, L.P. stage compressor piston.
3, I.P. stage compressor piston.
4, Retaining ring to hold lightly down flange of H.P. stage piston.
5, Grooves in piston.
6, Rings, six in number.

To permit of correct working alignment when under conditions of heat expansion, the H.P. stage piston is fitted independently and held down loosely by the retaining ring as shown to form a floating fit. The grooves shown improve lubrication and piston tightness Diameter of H.P. piston $= 5\frac{7}{8}$ in. and stroke $13\frac{3}{4}$ in.
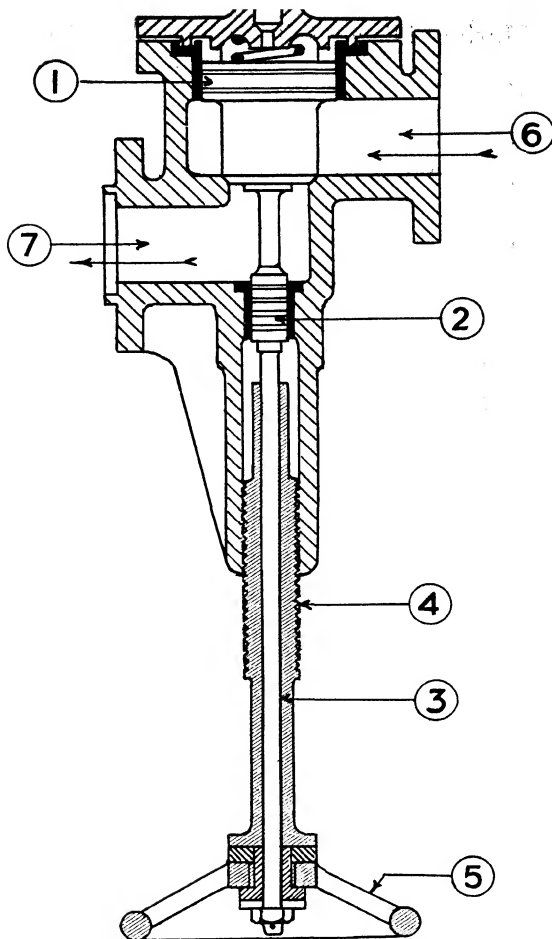
No. 511.—Starting Air Automatic Shut-Off Valve.
(H. & W. Engine.)
(*See also* p. 66.)

1, Differential piston valve with spring load combined with starting air pressure load (air inlet shown in cover).

2, Small piston on hand-actuating spindle.

3, Spindle of main piston valve, which, if freed from the screwed sleeve, allows the valve to lift by the effects of pressure difference.

4, Screwed sleeve by means of which the valve can, if required, be lifted, and which locks down the valve in the shut-off position after manœuvring operations are finished with. The screwed sleeve and hand wheel are in one, and are clear of the spindle.

5, Hand wheel of sleeve.

6, Air inlet from starting air tanks.

7, Outlet to air slide.

Previous to manœuvring, the hand wheel and sleeve are screwed upwards clear of the collar on the end of the valve spindle, and the starting air pressure acting on the differential piston lifts the valve and admits air to the main air slides.
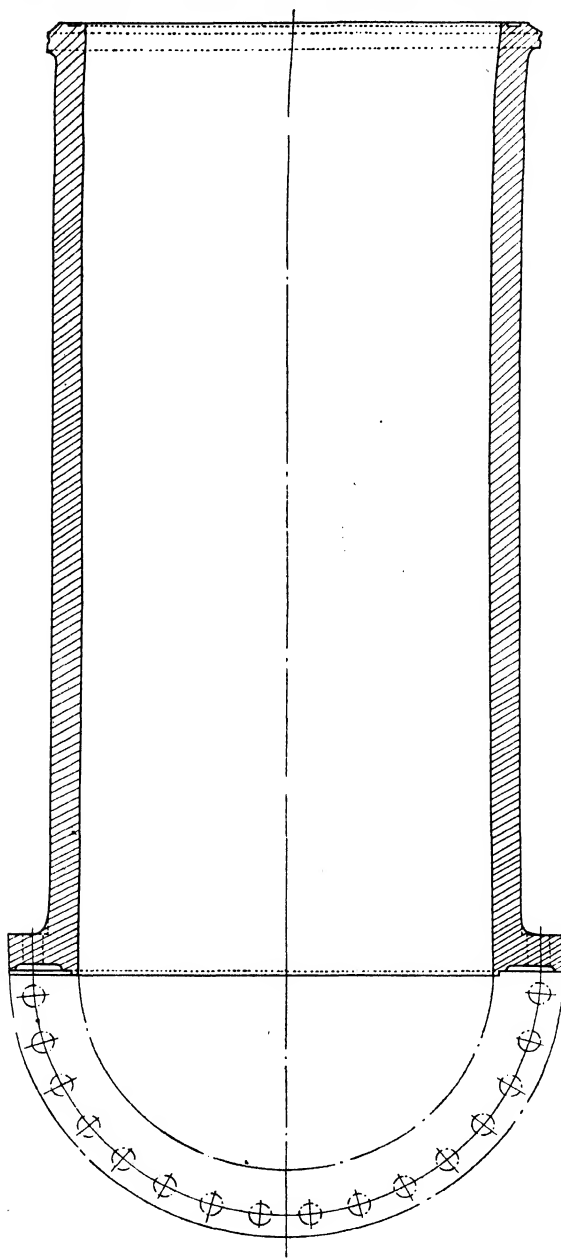
No 512.—Cylinder Liner.
(H. & W. Double-Acting 4-Cycle Engine.)

The liner is cast in one piece, expansion being allowed for at the metal to metal joint.
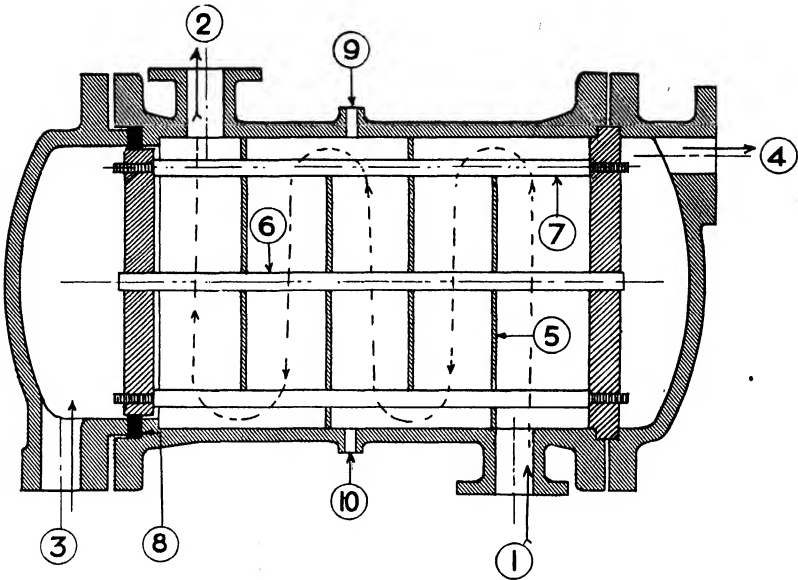
No. 513.—Lubricating Oil Cooler.

1, Heated oil inlet.

2, Cooled oil outlet.

3, Cooling water inlet.

4, Cooling water outlet.

5, Baffle plates.

6, Tube cooling surface (one tube only shown).

7, Stays.

8, Packing on which the tube plates slide when expanding on heating up.

9, Air escape.

10, Drain.

As will be noted, heat expansion is allowed for by having only one tube plate end secured in position, the other end being free to slide on the packing gland (8). The coolers of air compressors are arranged similarly. (See plate facing p. 80.)

The Clarkson Exhaust Gas Boiler. (No. 514.)

This is a vertical water tube boiler, having many short thimble tubes. The water space is between the inner and outer shells and in the thimble tubes, the open ends of which are expanded into the inner shell. The thimbles are of such a form that effective circulation is maintained within them without the use of internal tubes or plates.

The completely independent freedom of expansion of the boiler ensures that the tubes remain tight for the whole life of the boiler, and makes it possible to decarbonise the heating surface of the waste heat boiler by " burning off," which is the only effective way of decarbonising. This advantage alone gives the boiler a unique position for waste heat recovery from Diesel engines, and the boiler is a most efficient silencer, reducing the back pressure.

With the thimble tube boiler it is practicable to maintain the proper velocity during the whole passage of the exhaust gases through the staggered thimbles. In order to avoid the reduction of velocity in the latter stages, which usually results as the temperature and volume of the gases are reduced, the tubes are differentially spaced.

The manufacturers claim the following advantages for this boiler :— (1) A smaller size of thimble tube boiler will do the work more effectively and at less cost than is possible with any other type of boiler. (2) In consequence of its reduced size and weight, it can be fitted in place of silencers in the exhaust pipe run above the engine room. (3) Silencer boilers are fitted with alternative oil firing for use in port. (4) Ample accessibility for cleaning and inspection of all internal parts. (5) The ratio of heating surface to cubic capacity of the boiler is greater than with any other type of boiler.

Waste Heat Recovery.

The heat recovered is equal to about 50 per cent. of the B.T.U.'s contained in the exhaust gases in the case of 4-cycle engines, which gives about 1200 B.T.U.'s available per B.H.P. hour for the production of steam, or roughly, 1 lb. of steam per B.H.P. hour at 100 lbs. gauge pressure.

Example.—Exhaust gas temperature from engine to boiler $= 750°$ F.

Exit gas temperature from boiler $= 350°$ F.

Heat carried away in exhaust gases $= 30$ per cent.

Then, Heat available $= \left(\dfrac{750° - 350°}{750°}\right) \times 100 = 53 \cdot 3$ per cent.

Assuming a fuel consumption of, say, ·4 lb. per B.H.P. hour, and allowing 18800 B.T.U.'s per lb. fuel,

then, Heat recovered $= 18800 \times \cdot 4 \times \dfrac{30}{100} \times \dfrac{53 \cdot 3}{100} = 1202$ B.T.U.'s.

For steam at 100 lbs. gauge pressure the B.T.U.'s for evaporation from feed water at, say, 70° F. will be equal to $1115 + \cdot 3 \times 338° - 70° = 1146 \cdot 4$.

NOTE.—100 lbs. gauge = 115 lbs. absolute = 338° F. (from Table).

In 2-cycle engines the exhaust gas temperature is lower than in 4-cycle, the heat recovery is therefore less, and a lower pressure, say 80 lbs., may only be obtained.

Exhaust-gas Outlet

Safety Valve

Steam Valve

C

Pressure Gauge
A = 5'-0"
B = 15'-7½"
C = 2½"

Water Level

Water Gauge

Feed Inlet

A Dia.

B

Blow-down

Exhaust-gas Inlet

Exhaust-gas Inlet

Oil Burner

Oil Burner
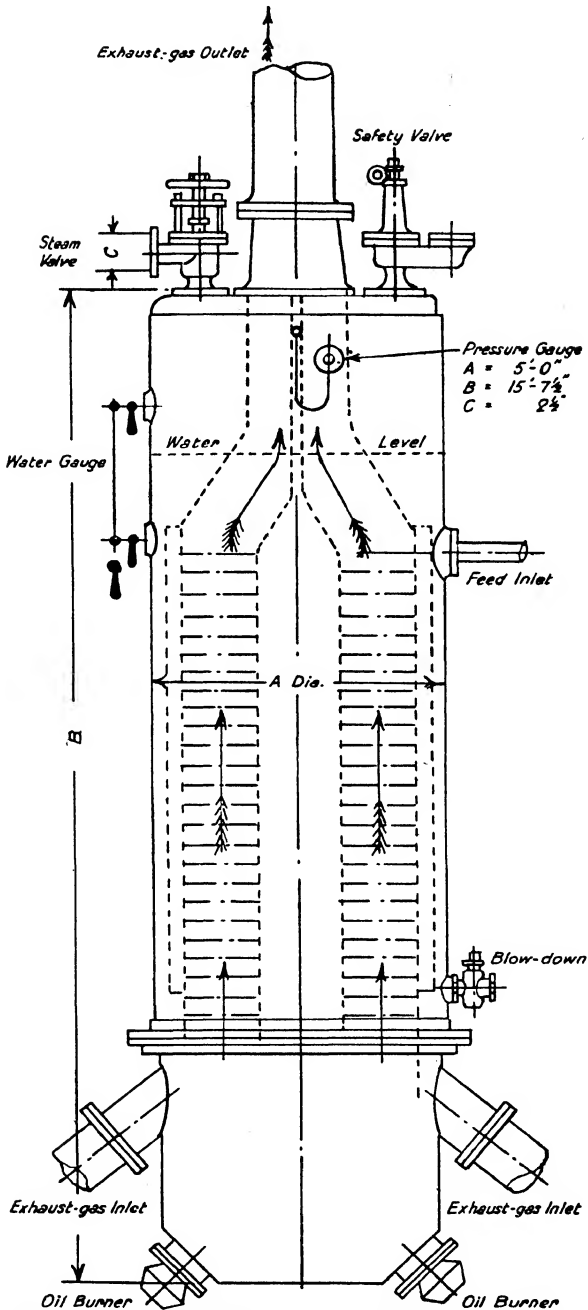
No. 514.—Sectional View of Clarkson Thimble Tube Exhaust Gas Boiler.

COCHRAN TYPE WASTE-HEAT BOILER

" WHILST exhaust gas boilers have been widely used in conjunction with marine Diesel machinery of the four-stroke type, they have not often been applied to two-stroke engines, on account of the low temperature of the exhaust gases.   In the ' Sheaf Holme,' however, a new type of waste-heat boiler, developed by Cochran & Co., has been installed in combination with a 1500 B.H.P. three-cylinder Doxford opposed-piston two-stroke engine.

The exhaust gases are not unduly cooled (the temperature being in the neighbourhood of 670° to 700° F.), and the large heating surface of the boiler, which is of the usual Cochran type, is specially designed for simultaneous oil firing and waste-heat recovery.

It has entirely separate nests of tubes and separate funnels for the two purposes, as indicated in the view shown.   This arrangement prevents all possibility of an explosion due to the ignition by the exhaust of oil vapour and air in the furnace or flues.

The boiler has a single nest of ordinary standard tubes in the oil-firing part, which, with the furnace, give a heating surface of about 500 sq. ft.

The tubes for the waste gases consist of two nests of smaller diameter tubes, one above the other, the gases being passed first through the top nest and returned through the lower nest.   The heating surface of the waste gas part of the boiler is 1390 sq. ft.   All three nests are between the same pair of tube plates.

Before installation in the ' Sheaf Holme ' the boiler was tested at Doxford Works, coupled to a three-cylinder engine of 2000 B.H.P., and it evaporated 0·84 lb. of water at 60° F. to steam at 100 lbs. per sq. in. per engine B.H.P. developed.   The back pressure produced by the boiler was low, being about 8 in. of water, or $\frac{1}{3}$ lb. per sq. in.

The drop in temperature of the exhaust gases through the boiler was rather more than 300° F., and the final temperature was 400°. The water circulation was good, the temperature of the water at the bottom, when firing with exhaust gases only, being very little below that of the water surrounding the tubes.

The oil-firing system is of the Wallsend low-pressure type."
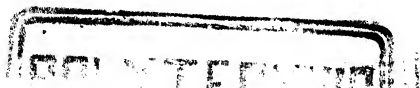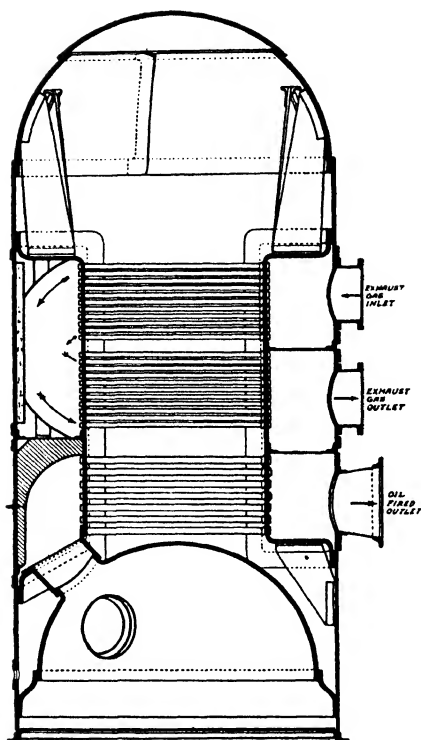
No. 515.—Cochran Waste-Heat and Oil-Fired
Auxiliary Boiler.
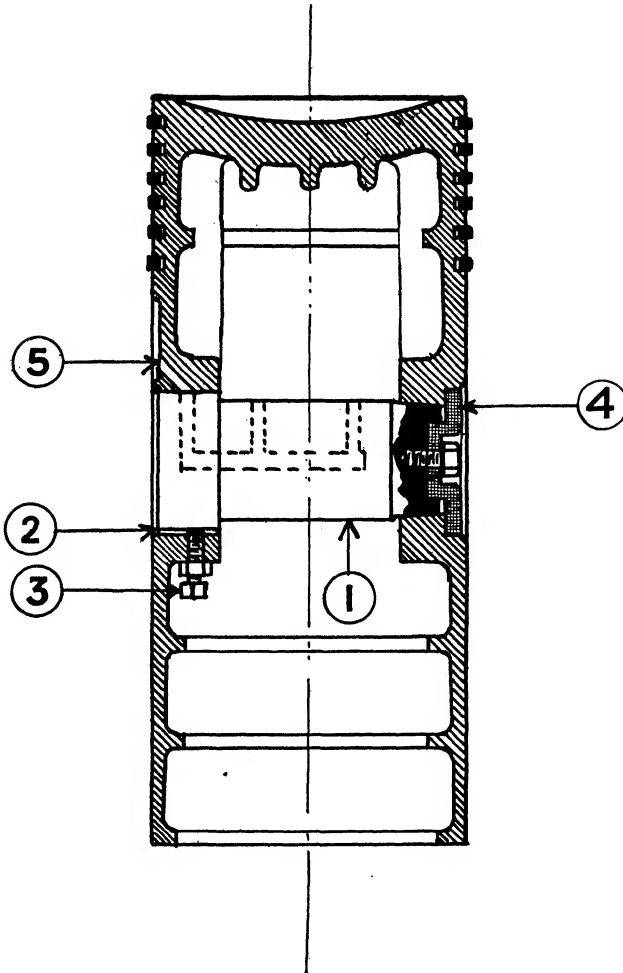
No. 516.—Trunk Piston of Semi-Diesel Engine.

1, Wristpin.
2, Feather.
3, Locking pin.
4, Securing plate.
5, Hole for piston lubrication inlet.

The diameter of the piston is less at top than at bottom, the difference being equal to about ·004″ per inch diameter.   For a piston, say, 16″ diameter the taper will be equal to 16 × ·004 = ·064″ less at top, and 16″ − ·064″ = 15·936″ diameter at top.
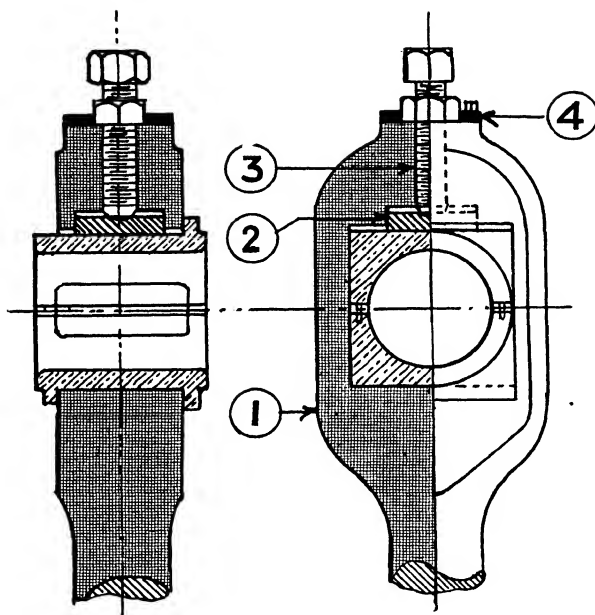
**No. 517.—Wristpin Bearing Brass of Trunk Type
Semi-Diesel Engine**

1, Slotted eye.

2, Adjustment pad.

3, Tightening screw.

4, Locking plate and pin.

Corrosion of Bearings due to Lubricating Oil.

In a paper written by Mr H. J. Young and read before the Institution of Petroleum Technologists recently, it was proved by exhaustive tests and experiments carried out by the writer of the paper that in many cases corrosion of bottom end bearings, main bearings, cylinder liners, etc., was caused by the presence of certain chemical forms of sulphur in the lubricating oil. It was further stated that up to the present the generally accepted tests applied by chemists gave no reliable indication as to the corrosive nature of an oil, although such may exist.

The author of the paper also mentioned that steel and white metal surfaces are both equally subject to corrosive action from lubricating oils which contain over a very small percentage of sulphuric acid.

It is interesting to know that Mr H. J. Young has devised a practical test for the corrosive property of an oil, and has patented the same.

Lloyd's Rules for Diesel Engine Crank Shafting.

When the maximum pressure in the cylinder does not exceed 500 lbs. per sq. in., the diameter of the crankshaft is to be not less than that obtained by the following rule:—

$$\text{Diameter of shaft} = \sqrt[3]{D^2 \times (AS + BL)}.$$

Where D = Diameter of cylinders in inches.

" S = Stroke in inches.

" L = Span of bearings in inches adjacent to a crank, measured from inner edge to inner edge.

For 6-cylinder 4-cycle engines A = ·089 B = ·056.

" 8 " 4 " " A = ·099 B = ·054.

" 4 " 2 " " A = ·099 B = ·054.

" 6 " 2 " " A = ·111 B = ·052.

Example 1.—Four-cycle engines with eight cylinders—

D = 29·5 in.   A = ·099.
S = 46 "   B = ·054.
L = 44 "

Then, $\sqrt[3]{D^2 \times (AS + BL)} = \sqrt[3]{29\cdot5^2 \times (\cdot099 \times 46 + \cdot054 \times 44)}.$

Therefore,

Diameter of shaft = $\sqrt[3]{29\cdot5^2 \times (\cdot099 \times 46 + \cdot054 \times 44)}.$

Therefore,

Diameter of shaft = $\sqrt[3]{870\cdot25 \times (4\cdot554 + 2\cdot376)} = 18\cdot2$ in. Ans.

Example 2.—Two-cycle engine with six cylinders.

D = 27·5 in.   A = ·111.
S = 39 "   B = ·052.
L = 48 "

Then, $\sqrt[3]{D^2 \times (AS + BL)} = \sqrt[3]{27\cdot5^2 \times (\cdot111 \times 39 + \cdot052 \times 48)}.$

Therefore,

Diameter of shaft = $\sqrt{27\cdot5^2} \times (\cdot111 \times 39 + \cdot052 \times 48).$

Therefore,

Diameter of shaft = $756\cdot25 \times (4\cdot329 + 2\cdot496) = 17\cdot5$ in. nearly. Ans.

Crank Webs.

For solid shafts breadth of webs = diameter of shaft × 1·33.

" " " thickness " = " " × ·56.

" built " " " = " " × ·625.

$$\text{Thickness of metal round eyes} = \sqrt{\frac{\cdot12 \times \text{Diameter}^3}{\text{Thickness}}}.$$

Example.—Find thickness of crank webs and thickness of metal round eyes, for a built crankshaft of 18 in. diameter.

Thickness of webs = 18 × ·625 = 11·25 in.

Metal round eyes = $\sqrt{\dfrac{\cdot12 \times 18^3}{11\cdot25}} = 7\cdot25$ in.

Therefore, Diameter of webs at eyes = 7·25 + 18 + 7·25 = 32·5 in.
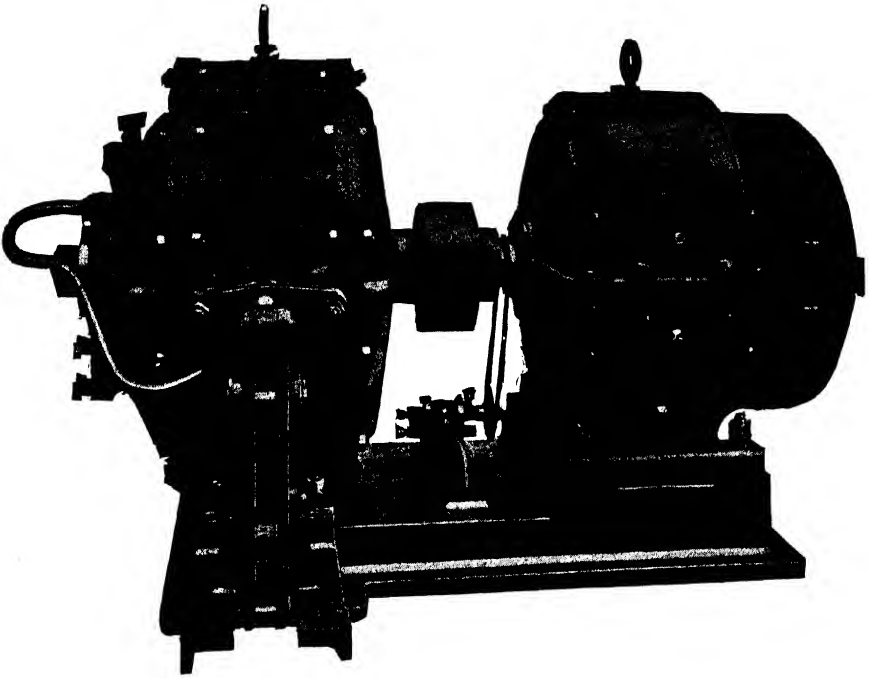
No. 518.—150 H.P. "Hele-Shaw" Pump.

DESCRIPTION OF THE "HELE-SHAW" PUMP

The "Hele-Shaw" pump is of the rotary plunger type. Its operation will be easily understood from the following short description :—

Nos. 519 and 520 show diagrammatically a section through the centre of the pump at right angles to its axis.

AB is the line along which stroke variation takes place.

C is the "cylinder body" in which are formed a number of radial cylinders. The cylinder body is coupled to and driven directly by the prime mover employed.

D is the fixed central valve on which the cylinder body revolves, and in which are the suction and delivery ports P and Q, communicating with the outside by passages.

The radial cylinders are fitted with pistons H, through each of which, parallel with the axis of D, is a gudgeon pin G. On these gudgeon pins are slippers J, fitting in an annular groove, and causing the gudgeon pin centres to travel in a circular path E shown on
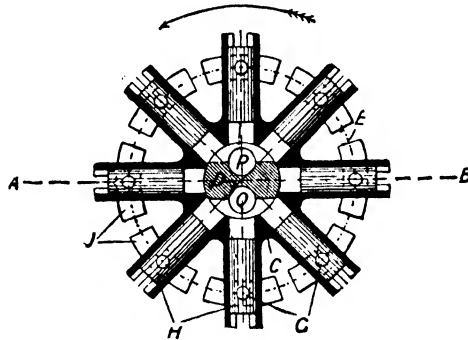
No. 519.
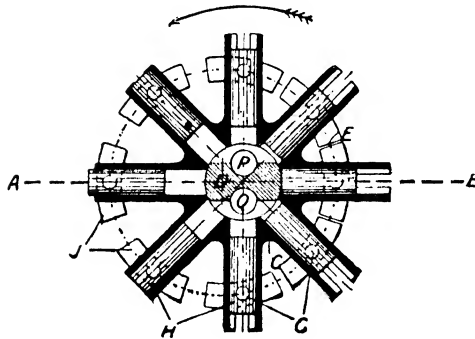
No. 520.

dotted lines; the position of this path can be changed by moving its centre along the line AB.

Suppose the cylinder body to be rotating in the direction of the arrows, and the position of the circular path E to be such that its centre coincides with the centre of D as in No. 519; no radial motion is then communicated to the pistons.

If the position of the centre of E be to the left as in No. 520, the pistons as they pass above the line AB recede from D and suck liquid through the port P, whilst the pistons below AB approach D and discharge through port Q.

If the position of the centre of E be to the right as in No. 521, then the pistons below AB recede from D, so that Q becomes the suction port and P the delivery port. The flow of liquid is therefore reversed without altering the direction of rotation.

In moving from the position of maximum delivery on one side
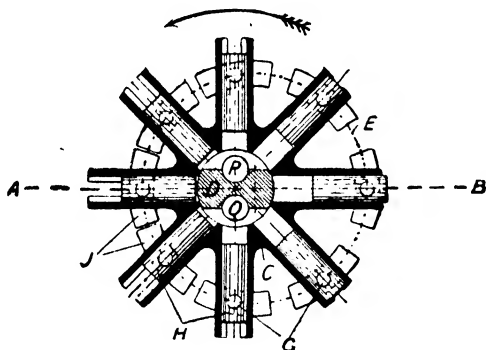
No. 521.

to that on the other, the discharge is gradually reduced until at the central position it ceases, after which it again increases to the maximum, but in the opposite direction the change from full forward to full reverse discharge is made without shock.

The slippers J traverse the whole surface of the path E once in each revolution, and their resistance at high speeds of revolution would be large, even if perfectly lubricated by running in a case full of oil. Further, the oil filling the case would be churned by the rotation of the pump and increase the resistance.

To decrease this resistance and thereby increase the efficiency of the pump the path E is formed as part of a floating ring which runs on bearings.
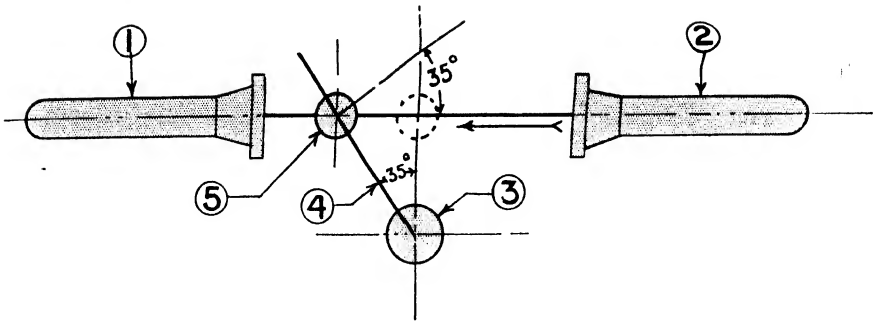
No. 522—Diagram of Electro-Hydraulic Steering Gear.

1, Port ram (looking forward).

2, Starboard ram (looking forward).

3, Rudder stock.

4, Tiller arm at maximum helm angle (35°).

5, Pump crosshead and guide at position of 35° helm.

Calculated Example.

Electric-Hydraulic Gear.

(Two-ram type.)

Diameter of rams = 12 in.

Centre of rams to centre of rudder stock = 30 in.

Diameter of rudder stock = 18 in.

Stress on rudder stock not to exceed 5000 lbs. $\boxed{''}$.

Max. angle of helm = 35°.

Find pressure P at which the bye-pass relief valve should be set to lift.

Rule.—$5 \cdot 1 \times$ T.M. = Dia.$^3 \times$ Stress $\boxed{''} \times$ Cos$^{\circ\,2}$.

Then $5 \cdot 1 \times 12^2 \times \frac{11}{14} \times$ P $\times$ 30 in. = $18^3 \times 5000 \times$ Cos 35° $\times$ Cos 35°.

Cos 35° = $\cdot 8192$, and $\cdot 8192 \times \cdot 8192 = \cdot 6710$,

so that $\qquad P = \dfrac{18^3 \times 5000 \times \cdot 6710}{5 \cdot 1 \times 12^2 \times \frac{11}{14} \times 30 \text{ in.}} = 1130$ lbs. $\boxed{''}$.

Notice that owing to the double angle involved in the pump crosshead and tiller arm movement the *square* of the cosine angle requires to be used, which proportionally reduces the ram pressure required with increase of helm angle.

Hele-Shaw Electric Hydraulic Steering Gears

(Messrs John Hastie & Co., Greenock)

Example of Steering Gear B.H.P. Calculation.

Given an Electro-Hydraulic steering gear having 2 single-acting rams 12 in. diameter working at a normal radius of 30 in. from centre line of rudder stock, maximum angle of rudder 35° each side of centre line. Time to put rudder from hard-over Port to hard-over Starboard is 30 secs.

Assuming that the " Turning Moment " on the rudder sets up a twisting stress of 5000 lbs. $\boxed{''}$ on the stock, which is 18 in. diameter, find the following :—

1. Turning moment in foot-tons.
2. Maximum working pressure on rams in lbs. $\boxed{''}$ (taking efficiency of rams and cylinders as 80 per cent.).
3. Find B.H.P. of electric motor (taking efficiency of Hele-Shaw pump as, say, 85 per cent.).

1. Turning moment $= \dfrac{d^3 \times S}{5\cdot1 \times 12'' \times 2240} = \dfrac{18^3 \times 5000}{5\cdot1 \times 12'' \times 2240} = 212\cdot7$ ft.-tons.

2. Max. W.P. $= \dfrac{\text{T.M.} \times 2240 \times \cos^2 \phi}{A \times \text{N.R.} \times E} = \dfrac{212\cdot7 \times 2240 \times \cdot6711}{113\cdot1 \times 2\cdot5 \times \cdot8} = 1414$ lbs. $\boxed{''}$.

Where $\cos^2 \phi =$ mechanical advantage due to " Rapson " wedge slide effect.

$\quad\quad$ A $=$ area of cylinder $\boxed{''}$.

$\quad\quad$ N.R. $=$ normal radius in feet from rudder stock centre to centre line of rams.

$\quad\quad$ E $=$ mechanical efficiency of gear.

3. Stroke of ram $=$ tangent of 35° $\times$ N.R.

$\quad\quad = \cdot7002 \times 30'' \times 2 = 42''$.

H.P. at gear $\quad = \dfrac{A \times P \times S'' \times 60 \text{ secs.}}{33000 \times 12 \text{ in.} \times 30 \text{ secs.}}$

$\quad\quad = \dfrac{113\cdot1 \times 1414 \times 42'' \times 60}{33000 \times 12'' \times 30} = 34.$

B.H.P. of electric motor $= \dfrac{34 \times 100}{85} = 40$ B.H.P.

NOTE.—Observe that the tangent of the rudder angle represents the effective stroke of the ram for any angle of helm.

Note.—Cos 35° $= \cdot8192$, and $\cdot8192^2 = \cdot6711$.
Tan 35° $= \cdot7002$.
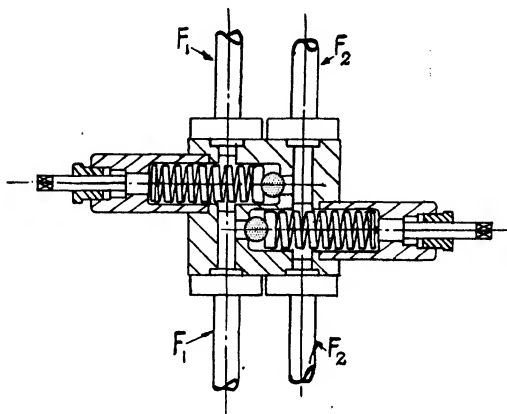
SECTION THRO' SHOCK VALVE
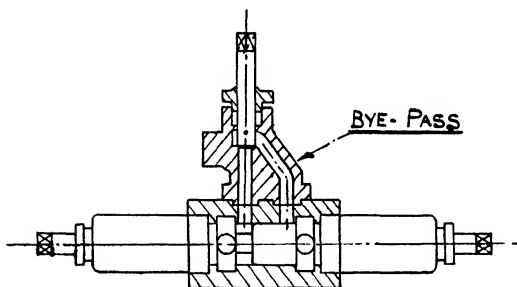
SECTION THRO' SHOCK VALVE

SHOWING BYE·PASS

524.—Shock Valve and Bye-Pass Valve.

(*See also* No. 523)

The double spring and ball shock valves shown are set to lift at a pressure of about 1200 to 1600 lbs. per sq. in., and are intended to allow the rudder to give way when subjected to heavy sea pressures.

The shock valves function to open up connection between the ram with the high pressure and that of the low pressure, say, from ram and cylinder F_1 to ram and cylinder F_2, or vice versa. The excess pressure forces the ball valve against the spring compression, which when overcome opens the cross connection as shown.

The bye-pass valve is only opened when charging up the system, or, if owing to breakdown, the hand gear is brought into operation so that the pressure may be equalised on either side and resistance eliminated.
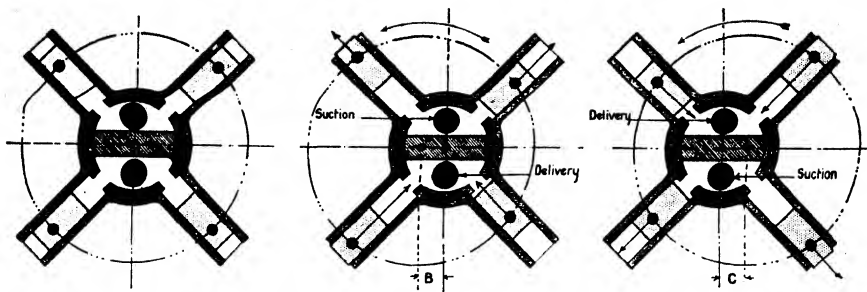
525.—"Hele-Shaw" Patent Multiple Plunger Pump.

The diagram sketches illustrate the principle of this pump as fitted for Electro-Hydraulic steering gear purposes.

The sketch on the left shows the pump running idly, the plunger travel circle and pump chamber travel circle being concentric.

The sketch in centre shows the pump in operation, the plunger travel circle being now eccentric (B on left) to the pump chamber circle, the upper port suction, and lower port delivery, as shown by the arrows.

The sketch on right also shows the pump in operation, but reversed in suction and delivery owing to the eccentricity being now on the right (C). The lower port now becomes the suction, and the upper port the delivery.

In the actual pump usually seven or eight small plungers are arranged to form a set.

It should be noted that the direction of rotation remains constant.

The pump is driven by a shunt wound motor.
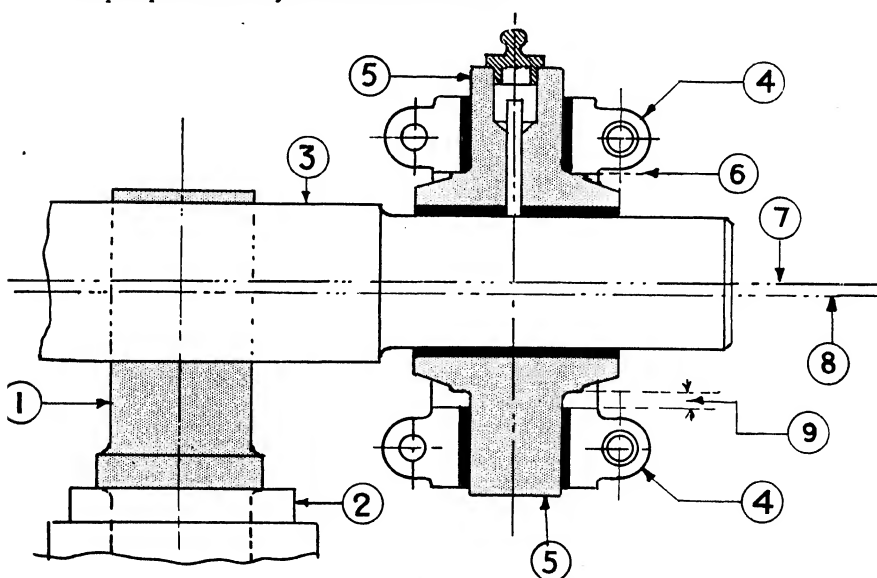
526.—Allowance for Rudder Wear Down.

1, Rudder stock.	5, Pivoted swivel ball bearing.
2, Fitted band.	6, Touch fit nearly.
3, Tiller arm.	7, Centre line of tiller arm.
4, Ram crossheads.	8, Centre line of cylinders and rams.

9, Allowance for rudder wear down, say $\frac{5}{8}$ in. to $\frac{3}{4}$ in.

NOTE.—The tiller arm swivel bearings 5 rotate as the ram crossheads push over the tiller arm and rudder, and thus accommodate themselves to the slewing movement.

Excessive Heating of Compressor under Conditions of Reduced Output.

The following calculations show why serious heating may develop in the H.P. compressor stage when running under low loads and correspondingly reduced air outputs. The compression ratio index has been assumed as 1·3 for the H.P. stage, owing to the fact that the work done is more nearly adiabatic in nature than in the L.P. and M.P. stages owing to the small surface area available for cooling (say 6½ in. diameter against 24 in. diameter in the L.P. stage).

Rule—

$$T_2 = T_1 \times \left(\frac{P_2}{P_1}\right)^{\frac{1.3-1}{1.3}}.$$

Where $T_1 =$ Initial temperature of air (absolute).

,, $T_2 =$ Final   ,,   ,,   ,,   after compression.

,, $P_1 =$ Suction air pressure absolute.

,, $P_2 =$ Compression air pressure absolute.

,, $1·3 =$ Index for approximate adiabatic expansion or compression.

(A) Normal Output.

$P_1 = 220$ lbs. absolute.

$P_2 = 1000$ lbs. absolute.

$T_1 = 90° + 460° = 550°$ absolute.

Then. $\qquad T_2 = 550 \times \left(\frac{1000}{220}\right)^{\frac{1.3-1}{1.3}}.$

,, $\qquad\qquad T_2 = 550 \times 4·545^{·23}.$

,, $\qquad\qquad T_2 = 2·7404 + (·6566 \times ·23).$

,, $\qquad\qquad T_2 = 2·8914.$

$\qquad\qquad$ Anti-log $2·8914 = 778·7°$ absolute.

And $\qquad\qquad 778·7° - 460° = 318·7°$ Fahr. Ans.

Note.—Log $550 = 2·7404$. Log $5·454 = ·6566$.

(B) Reduced Output.

$P_1 = 130$ lbs. absolute.

$P_2 = 1000$ lbs. absolute.

$T_1 = 90° + 460° = 550°$ absolute.

Then, $\qquad T_2 = 550° \times \left(\frac{1000}{130}\right)^{\frac{1.3-1}{1.3}}.$

,, $\qquad\qquad T_2 = 550 \times 7·69^{·23}.$

,, $\qquad\qquad T_2 = 2·7404 + (·8859 \times ·23).$

,, $\qquad\qquad T_2 = 2·9441.$

$\qquad\qquad$ Anti-log $2·9441 = 879·2°$ absolute.

And $\qquad\qquad 879·2° - 460° = 419·2°$ Fahr. Ans.

Note.—Log $550 = 2·7404$. Log $7·69 = ·8859$.

Note.—If, say, the L.P. clearance volume is increased by wear down, the terminal pressure of L.P. compression may remain as before, but the quantity, or weight, of air delivered will be reduced and the successive pressure at each stage will be less.
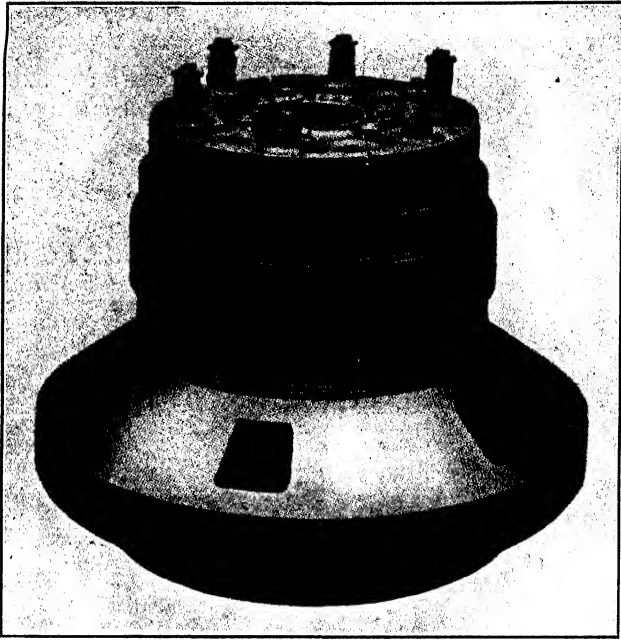
No. 527.—"In-ex." Valve Casing.
(Werkspoor Engine.)

The valve casing is comparatively light, has a seat diameter of only 60 per cent. of the cylinder bore, and can be very easily removed and replaced if necessary, a spare being carried for each valve casing. From each valve a separate conduit leads to a cone-shaped seat on the valve casing. The latter is surrounded by an oscillating sleeve in which twelve apertures are made, six leading horizontally to the exhaust belt, and the other six vertically to the inlet belt. The sleeve is moved by an eccentric on the camshaft, and this motion brings alternatively the exhaust belt and the inlet belt into communication with the ports in the valve cage. A suitable labyrinth packing is provided between the two belts. The valve cage is cooled, but cooling is not provided in the sleeve.

The "In-ex." valve cage accommodates six small spring load valves which are used for the dual purpose of timing the admission of the induction air and the egress of the exhaust gases. The "In-ex." valve housing is seated on the cylinder head.
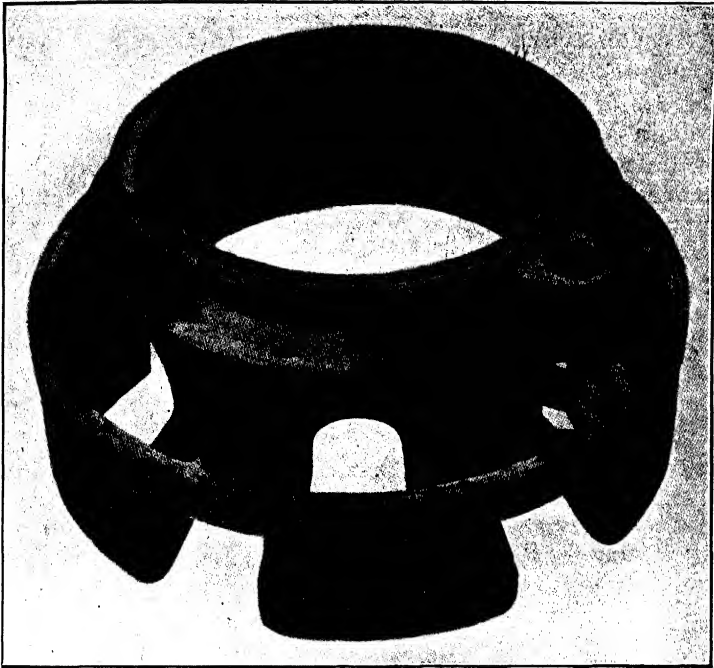
No. 528.—Sleeve of "In-ex." Valve.

(Werkspoor Engine.)

Around the upper part of the " In-ex." valve cage a brass carrier ring is fitted, the object of the ring being to take the weight of the moving sleeve valve and prevent the conical bearing surfaces lower down from making actual contact.

Immediately below the brass carrier ring is a cast-iron Ramsbottom ring which bears lightly against the bore of the sleeve valve and prevents exhaust gas from reaching the carrier ring and causing it to run dry. The gap between the ends of the spring sealing ring when in place should be 2 mm. (·080 in.).

At the wall which separates the air induction belt from the exhaust belt another ring of special design is fitted to seal the working clearance space and prevent exhaust gas from reaching the air induction belt and so contaminating the charge of fresh air going into the cylinder. The gap at the ends of this ring when in place = ·080 in.

The working clearance between the moving sleeve valve and the stationary parts of the cylinder head are most important.

Solid Injection Cylinder Fuel Valve.

One type of cylinder fuel valve is fitted with a close ended cap which contains six small atomising openings of ·017 in. diameter. The valve is of the needle type and lifts upwards against the spring load compression by means of the fuel injection pressure acting on a small differential shoulder machined on the valve spindle.

The valve casing has a drilled hole throughout its length, and when lift occurs the fuel oil flows downwards through the hole to pass through the openings in the cap into the cylinder. As common to recent practice, the period of fuel closing or cut off is regulated by means of a special spill valve which functions to break the delivery pressure and returns the surplus fuel to the suction side of the fuel pump.

The spill valve consists of a cam actuated plunger with a stroke similar to that of the fuel pump plunger, the spill plunger being bevel machined to form a released space through which the surplus fuel is spilled and bye-passed back to the suction side of the fuel pump. The spill plunger can be partly rotated by the control gear so that the cut off may be varied by means of the position of the machined portion of the plunger or spindle.
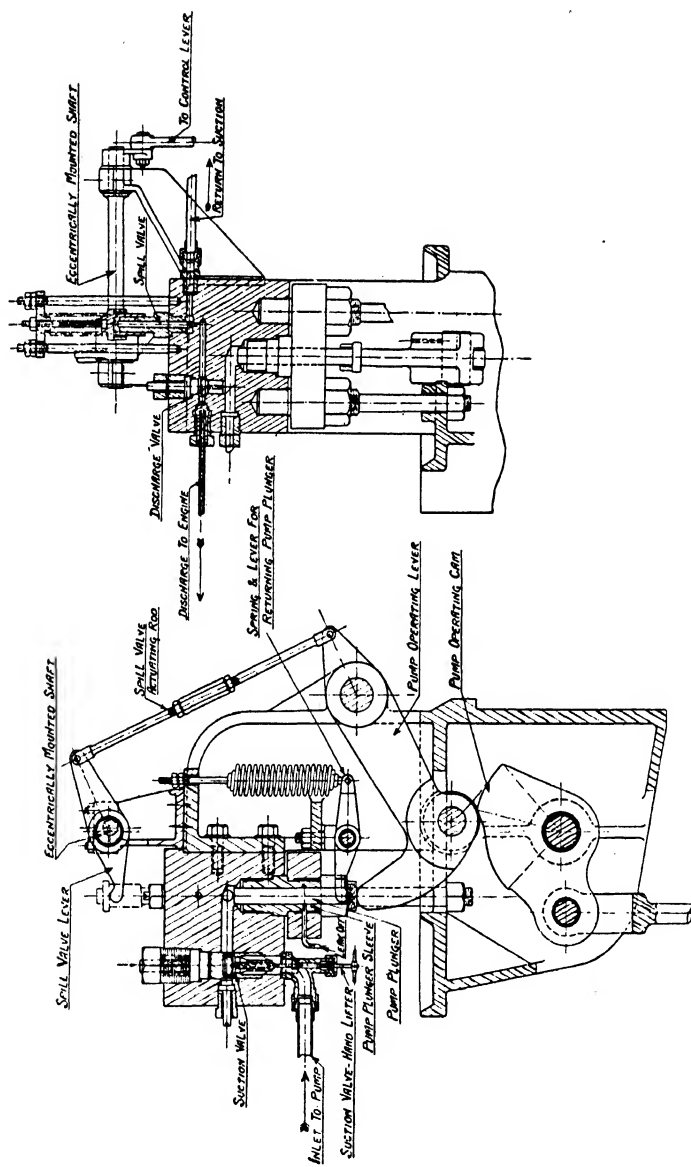
No. 529.—Fuel Injection Pump and "Spill" Valve of Still Engine.

The spill valve is seen at the top of the pump chest together with the actuating gear and eccentric control movement (also see p. 745).

FUEL PUMP CALCULATIONS

Data.

2-Cycle Engine

B.H.P. per cylinder = 500.
Revolutions = 115.
Diameter of plunger to be, say, 1 in.
Maximum tappet stroke to be, say, $\frac{3}{4}$ in.
Fuel oil = ·864 gravity.

Then,   Lbs. per cubic foot = 62·5 × ·864 = 54.

Allow full pump capacity equal to supply, say 1 lb. fuel per B.H.P. hour, so that losses in efficiency may be covered.

Then,

Cubic inches fuel per minute at full pump capacity $= \dfrac{500 \times 1 \times 1728}{54 \times 60} = 267.$

So that,   Stroke $= \dfrac{267}{1^2 \times ·7854 \times 115} = 2·9''$, say 3″.

The ratio of tappet clearance to tappet stroke is equal to ratio of effective stroke of pump to full stroke.

Then,   If tappet clearance = 0, effective delivery stroke = 0.
„   „   „   = $\frac{3}{4}$,   „   „   = 3″.

And in the same ratio for any required fuel delivery, therefore,

$$\frac{\text{Tappet clearance}}{\text{Tappet stroke}} = \frac{\text{Effective stroke}}{\text{Full stroke}} .$$

Example A (referring to the data given).

Allow, say, a fuel consumption at full power (500) of, say, ·42 lb. per B.H.P. hour.

Then,   Tappet clearance   = ·75″ × ·42 = ·315″.
„   Effective delivery stroke = 3″ × ·42 = 1·26″.

Note.—1 lb. fuel = ·75″ tappet clearance (full).
        „   = 3″ pump stroke (full).

Example B.

Find the effective stroke of fuel pump and required tappet clearance for same when the power is reduced to 250, and allowing a fuel consumption of, say, ·45 lb. per B.H.P. hour.

Then,   Effective stroke required $= \dfrac{250 \times ·45 \times 3''}{500 \times 1} = ·675''$.

Also,   Tappet clearance $= \left(\dfrac{·675''}{3''}\right) \times ·75'' = ·168''$.

Note.—·675 ÷ 3″ = ·225 ratio of effective stroke to full stroke, and therefore ratio of tappet clearance to tappet stroke.

Example C.

Find effective pump stroke, also tappet clearance to give same,, when the power is raised to an overload of, say, 550 B.H.P. per cylinder, allowing a fuel consumption of, say, ·44 per B.H.P. hour at this power.

Then, Effective stroke $= \dfrac{550 \times \cdot 44 \times 3''}{500 \times 1} = 1 \cdot 45''$.

Also, Tappet clearance $= \left(\dfrac{1 \cdot 45''}{3''}\right) \times \cdot 75 = \cdot 362''$.

For any other power the same ratios hold good, so that the tappet regulating gear and governor control gear require to be designed on this basis.
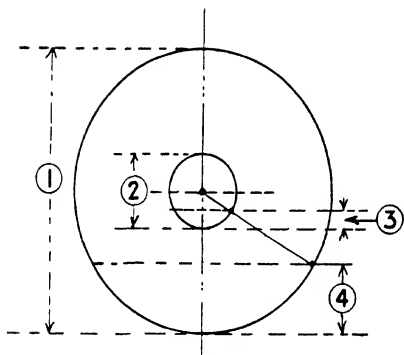
No. 530.—Fuel Pump Stroke and Tappet Diagram.

1, Fuel pump stroke.
2, Tappet stroke.
3, Tappet clearance.
4, Effective stroke of pump.
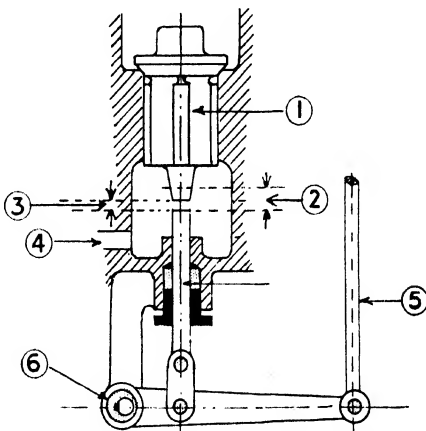
No. 531.—Fuel Pump Suction Valve and Tappet.

1, Suction valve.
2, Tappet stroke.
3, Tappet clearance.
4, Fuel inlet.
5, Regulating rod of tappet.
6, Eccentric control from governor for tappet clearance.

Note.—In the case of a 4-cycle engine the fuel consumption per minute would be taken as equal to half that of a 2-cycle engine.

Crankshafting.

The crank webs, pins, and shaft lengths are usually forged separately, but in Diesel practice the crank webs and pins are often machined out of one solid ingot. The webs (if loose) are shrunk on to the crankpins and shaft lengths, the shrinkage allowance being equal to about $\dfrac{1\cdot5}{1000}$ in. $= \cdot0015$ in. per inch diameter. The crankshafting is not subject to axial thrust, this being absorbed by the thrust block.

Wear Down of Propeller Shaft.

It is inadvisable to allow the wear down of a propeller shaft to exceed, say, $\frac{3}{8}$ in., otherwise a broken shaft may be the result.

To test for wear down, remove the check rings and try feelers between the upper diameter of the shaft and the hardwood blocks of the stern bush. If the wear down is excessive, the stern bush will require to be withdrawn, refitted with wood, and bored out (shop repair).

Stresses on Propeller Shafts.

Propeller shafts are subject to the effects of combined twisting and bending moments which set up tensile and compressive stresses on the outer fibres of the material. For this reason propeller shafting and crank shafting are of heavier construction than the tunnel lengths of shafting.

Rubber Bearings.

In America, rubber bearings of the " Cutless " type are often fitted to pumps and to vessels' stern tubes, and appear to have given satisfactory results after reasonable service.

For the after bush of a stern tube the rubber bearing takes the place of the lignum-vitæ strips, and consists of a tube of tough rubber moulded closely to the inside of the usual stern bush.

The rubber tube is provided with a spiral groove running from one end to the other to act as an efficient waterway for water lubrication purposes. The advantages claimed for the rubber bearing include the following :—

1. Possesses low-friction coefficient.
2. Absorbs vibration shocks on the shafting.
3. Eliminates scoring of bush.
4. The deflection in a given length is very small.
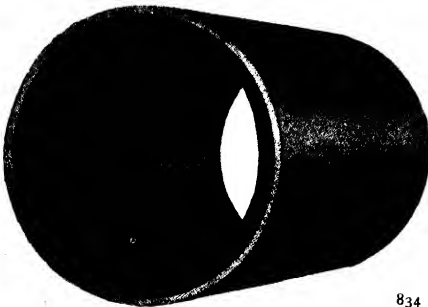
No. 532.—Cutless Type Rubber Bearing, as fitted to Stern Bushes.

Testing for Alignment of Tunnel Shafting.

If through grounding of the vessel or other causes it is desired to test if the vessel has hogged or sagged with corresponding misalignment of the shafting, the following method can be applied :—

1. Prepare three wooden dummy bulkheads as shown in the sketch, two of which are provided with a $\frac{1}{16}$-in. diameter hole cut at a distance above the shaft diameter of, say, exactly 10 in., and the third one with a rectangular hole, say 6 in. by 4 in., cut on the 10-in. vertical measurement.
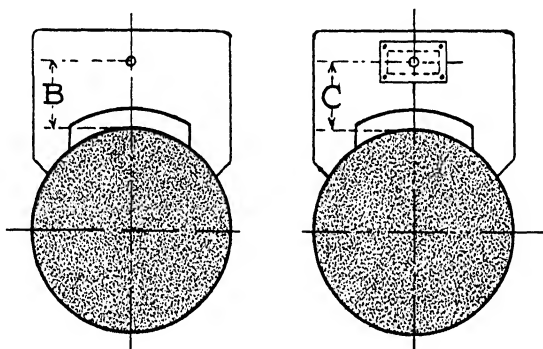
No. 533.

2. Fix one board on the forward end of the shafting and the other right aft at the propeller shaft end, with an electric light in a box placed behind the $\frac{1}{16}$-in. diameter sight hole.

3. Fix the portable board on the shafting at any desired inter-mediate position, and when sighting through the three openings mentioned, have a man in position to cut off the light both vertically and horizontally by means of a wood strip on the portable board, afterwards drawing lines to correspond at the sides, also top and bottom.

4. Cover up the rectangular hole with a piece of tin and continue the lines drawn across both vertically and horizontally, the inter-section of which will be the correct centre line of the shafting, as can be proved by boring out a small hole through which the light will then be visible from end to end.

5. Measure to test if this hole is exactly the same distance from the shaft diameter as those in the other boards, and if not, the shaft is out of line, either high or low as the case may be.

Description of Bevis-Gibson Torsion Meter.

Two blank discs are mounted on the shaft at a convenient distance apart. Each disc is pierced near its periphery by a small radial slot, and these two slots are in the same radial plane when no power is being transmitted and there is no twist on the shaft. Behind one disc is fixed a bright electric lamp masked, but having a slot cut in the mask directly opposite the slot in the disc. At every revolution of the shaft, therefore, a flash of light is projected along the shaft towards the other disc. Behind the other disc is fitted the torque-finder, an instrument fitted with an eye-piece and capable of slight circumferential adjustment. The end of the eye-piece next its disc is masked except for a slot similar and opposite to the slot in the disc. When the four slots are set in line, a flash of light is seen at the eye-piece every revolution, and if the shaft revolves quickly enough the light will appear to be continuous. This effect is apparent at anything over 100 revolutions per minute. At lower speeds the flash is seen to be intermittent, but this in nowise effects the accuracy and reliability of the result. At each end of the shaft, therefore, we have what is virtually an instantaneous shutter fixed, be it noted, directly to the shaft, and there is no connecting link or gear between the discs, either mechanical or electrical, except the beam of light which flashes once in each revolution clear through the two shutters. Let us suppose now the shaft to be transmitting power. One disc lags behind the other by a definite amount, and although three of the slots are still in line, the fourth slot, namely, that in the lagging disc, effectually blanks the flash and no light is seen at the eye-piece.

This is where the function of the " torque-finder " comes in. To pick up the light again the eye-piece must be moved by an amount equal to the circumferential displacement of the lagging disc. This is accomplished by manipulating the micrometer spindle of the torque-finder, on which is a scale and vernier graduated in degrees. While the scale is fixed its vernier moves with the eye-piece, and the graduations are so marked that by the aid of a simple microscope, conveniently hinged, differences of $\frac{1}{100}$ of a degree can be readily discerned. For shafts of ordinary size the scale is set at 13·6 in. radius from the centre of the shaft, so that the degrees are about $\frac{1}{4}$ in. apart. One-hundredth of a degree, therefore, means $\frac{1}{100}$ of $\frac{1}{4}$ in., or $\frac{1}{400}$ of 1 in. As an ordinary shaft twists one degree in 10 ft. at full power, it is, therefore, possible to get the shaft horse power to within 1 per cent. of full power. But as it is frequently possible to fit the discs 40 or 50 ft. apart, even this accuracy may be improved upon, and powers ascertained to within one-fourth of 1 per cent. of full power.
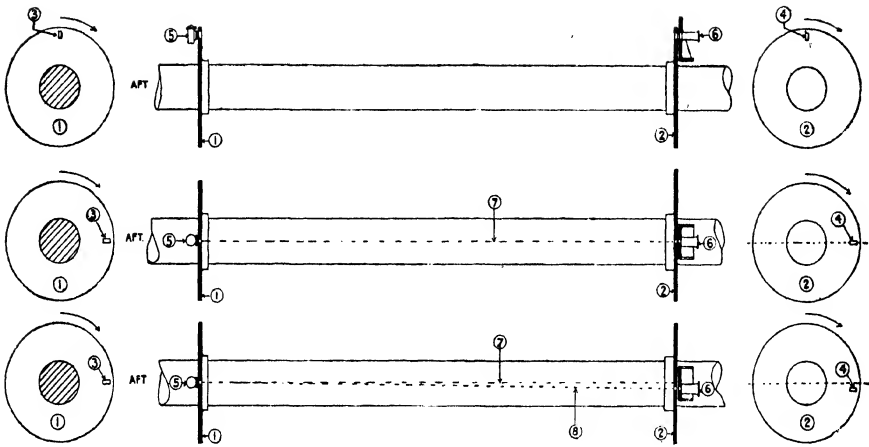
No. 534.—The Bevis-Gibson Flash Light Torsion Meter.

Upper View, Side Elevation; Lower Views, Plan.

1, After disc.

2, Forward disc.

3, Slot in after disc.

4, Slot in forward disc.

5, Lamp.

6, Torque-finder.

7, Imaginary line running along shaft.

8, Imaginary line shown out of position due to torque on shaft.

NOTE.—The lower view shows the shaft transmitting power and the torque-finder moved round to pick up the flash and so measure the torque or twist of the shaft. The relative positions of the slots in each disc with the shaft transmitting power are shown on the end views of the bottom plan.

Calibration of Shafts for Torque Measurement.—To calculate the shaft horse power by torsion meter it is requisite to obtain a constant for the torque of the shaft, as this varies with different makes and size of shafting. To attain this result the shafting requires to be calibrated, and the usual method of doing this is as follows :— The shaft length to which the torsion meter is to be attached is laid along the shop floor and bolted together by the coupling bolts belonging to the shaft. This length of shafting is levelled up, and is laid on wood blocks faced with sheet iron. The forward end of the shaft is rigidly bolted to a lever or arm, and on the end of same large weights are laid. At the other or after end of the shaft another lever is bolted, care being taken to see that in both cases there is no play in the holes. This lever is adjusted so that it travels an equal distance above and below the centre of the engine shaft when the weights are applied. At equal distance along the shaft light clamps are fixed, which have extended arms, on the end of which is fixed a piece of planed wood. The distance from centre of shaft to the wood varies according to size of shaft, and is often arranged to give a reading of 8 to 1, that is, $\frac{1}{8}$ in. actual shaft twist is recorded as 1 in. on the board. These arms are also levelled, and in front of them suitable platforms are arranged on which to work a surface gauge. The movable end of the shaft is left unweighted, and lines are drawn across the wood on the end of the arms. Weights are now put on the lever at aft end of shaft, these weights being applied at a given distance from centre of shaft, and when sufficient weight has been applied other lines are drawn across the wood on the end of arms. More weight is applied and more lines drawn as the weight is increased. The distances between the marks are measured, and indicate the torque or twist of the shaft due to the weight applied at the leverage selected. From this operation constants are obtained which are used in the formula employed in calculating the shaft horse power by torsion meter readings.

Determination of S.H.P. Constant from Shaft Calibration.

The twisting moment or torque is equal to the length or leverage of crank arm in feet multiplied by the load applied at the end.

Example.—During the shop calibration tests of a shaft length, the weight applied at a leverage of 6 ft. is equal to 30000 lbs., the diameter of shaft being 12 in., the twist as recorded on the marking boards being, say, 1·25° in a longitudinal distance of 20 ft.

Now,

$$\text{B.H.P.} = \frac{\text{T.M.} \times 2 \times 3\cdot1416 \times \text{Revs.}}{33000} = \frac{30000 \times 6 \times 2 \times 3\cdot1416 \times \text{Revs.}}{33000},$$

and in the present case,

$$\text{B.H.P. for } 1° \text{ of twist} = \frac{30000 \times 6 \times 2 \times 3\cdot1416 \times \text{Revs.} \times 1°}{33000 \times 1\cdot25°},$$

and for any other case,

$$\text{B.H.P.} = \frac{30000 \times 6 \times 2 \times 3\cdot1416 \times \text{Revs.} \times \text{Angle of twist}}{33000 \times 1\cdot25°}.$$

Now, cancelling out,

$$\text{Constant} = \frac{30000 \times 6 \times 2 \times 3\cdot1416}{33000 \times 1\cdot25^{\circ}} = 27\cdot42.$$

Then, in all cases,

$$\text{B.H.P.} = 27\cdot42 \times \text{Angle of twist} \times \text{Revs.}$$

Example.—The torsion meter reading is $1\cdot5^{\circ}$ at 95 revolutions: find the B.H.P. of the engine.

Then,
$$\text{B.H.P.} = 27\cdot42 \times 1\cdot5 \times 95 = 3907\cdot35.$$

The Propeller Law.

The relationship existing between the square of the revolutions and the torque or twisting moment applied to the shaft through the medium of the B.H.P. (under conditions of constant slip) is known as the " propeller law," and this includes a constant which varies with each engine tested.

The expression of propeller law is as follows :—

$$\text{Torque} = \text{Constant} \times \text{Revs.}^2$$

Now,
$$\text{Torque} = \frac{\text{B.H.P.} \times 33000}{2 \times 3\cdot14 \times \text{Revs.}} = \text{ft.-lbs.}$$

Then,
$$\text{Torque} \div \text{Revs.}^2 = \text{Constant.}$$

The constant is determined from the B.H.P. of the engine as taken during the shop trials when driving, say, a Froude type water brake resistance and assuming constant slip.

Again,
$$\text{Revs.} = \sqrt{\frac{\text{Torque}}{\text{Constant}}}.$$

Example.—Referring to the " Marine Oil Engine Trials Committee " results of the T.S.M.V. " Cape York," fitted with Hawthorn Leslie-Werkspoor 4-cycle single-acting engines, the B.H.P. developed during the shop trials was 1020 at 125 revolutions.

Then,
$$\text{Torque} = \frac{1020 \times 33000}{2 \times 3\cdot14 \times 125} = 42878 \text{ ft.-lbs.}$$

And
$$\text{Constant} = \frac{42878}{125^2} = 2\cdot74.$$

To find the calculated revolutions for a torque of, say, 10700 ft.-lbs.

Then,
$$\sqrt{\frac{10700}{2\cdot74}} = 63 \text{ nearly.}$$

Calculation of B.H.P. from Torque.

Rule,   B.H.P. $= \dfrac{\text{Torque} \times 2 \times 3\cdot14 \times \text{Revs.}}{33000} = \dfrac{\text{Torque} \times \text{Revs.}}{5250}$.

Note.— $\dfrac{33000}{2 \times 3\cdot14} = 5250$ constant.

Shaft Torque Tests from Practice.

(Engine Trials Committee.)

T.M.V. " Cape York "—

Propeller law = Torque = Constant × Revs.

At full load = 1020 B.H.P. and 125 revs.

Torque from above rating = 42800.

Then, $42800 = \text{C} \times 125^2$

So that $\text{C} = \dfrac{42800}{125^2} = 2\cdot74$ nearly.

Again,   Torque $= 2\cdot74 \times \text{Revs.}^2$

Then,   Torque at 63 revs. $= 2\cdot74 \times 63^2 = 10875$.

T.M.V. " Dolius "—

$\text{C} = 54700 \div 120^2 = 3\cdot8$ nearly.

Then,   Torque $= \text{C} \times \text{Revs.}^2$

,,   ,, $= 3\cdot8 \times 60^2 = 13680$.

M.V. " Pacific Trader " (Single Screw)—

$\text{C} = 175000 \div 87^2 = 23\cdot12$.

Then,   Torque $= \text{C} \times \text{Revs.}^2$

Torque at 43 revs. $= 23\cdot12 \times 43^2 = 42748$.

M.V. " British Aviator " (Single Screw)—

$\text{C} = 165000 \div 86^2 = 22\cdot3$.

Then,   Torque $= \text{C} \times \text{Revs.}^2$

,,   ,, $= 22\cdot3 \times 43^2 = 41232$.

Also,   Revs. $= \sqrt{\dfrac{\text{Torque}}{\text{C}}}$.

Then,   Revs. $= \sqrt{\dfrac{123750}{22\cdot3}} = 74\cdot5$ revs.

Note.—The results obtained from torsion meter readings would agree with those obtained by the "propeller law" if the readings taken were absolutely accurate and the slip constant.

The Froude Water Dynamometer.

A dynamometer which is much used at present is the Froude water dynamometer, a piece of testing apparatus, designed on scientific lines, for ascertaining the brake horse-power of motors, engines, and turbines.

The whole of the power developed is absorbed in the machine, from which it passes away in the form of heat. The dynamometer, at the same time, is fitted with carefully made weighing attachments, so disposed as to measure with extreme accuracy the amount of power being developed. When testing engines, it is found a great advantage to have unquestionably reliable data of each individual engine, and this, it is claimed, is what the Froude water dynamometer gives, so that now most of the leading firms manufacturing engines have them tested by means of a " Froude." It is also to be noted that the " tuning up " of an engine is very appreciably expedited by the aid of this piece of apparatus.

Essentially this machine consists of similar metal castings, each consisting of a boss and a circumferential annular channel which are placed face to face on a shaft to which A is keyed on, B being free (sketch No. 536). There is thus formed a ring tube of elliptical section. Each channel is divided, by equally spaced vanes inclined at an angle of 45°, into a series of pockets. When A is rotated and B is held still, centrifugal action sets up vortex currents in the water in the pockets ; in this way a continuous circulation is caused between A and B, and the resulting changes of momentum give rise to oblique reactions.

The moments of the components of these actions and reactions, in a plane to which the axis of rotation is at right angles, are the two aspects of the torque acting, and therefore the torque acting on A through the shaft is measured by the torque required to hold B still.

The revolving part represents the propellers of the ship whose engines are being tested, and the outer casing is held from turning by a suitable arrangement of levers and weighing apparatus.

A section through the Froude standard water dynamometer is shown in No. 536.

The main shaft supports a rotor revolving inside a casing through which water is circulated to provide the hydraulic resistance, and simultaneously to carry away the heat developed by the conversion of the power into thermal effect.

In each face of the rotor are formed pockets of semi-elliptical cross section, divided one from another by means of oblique vanes. The internal faces of the casing are also pocketed in the same way.

When in action the rotor discharges water at high speed from its periphery into the spaces formed in the casing, by which it is then returned at diminished speed into the rotor pockets at a
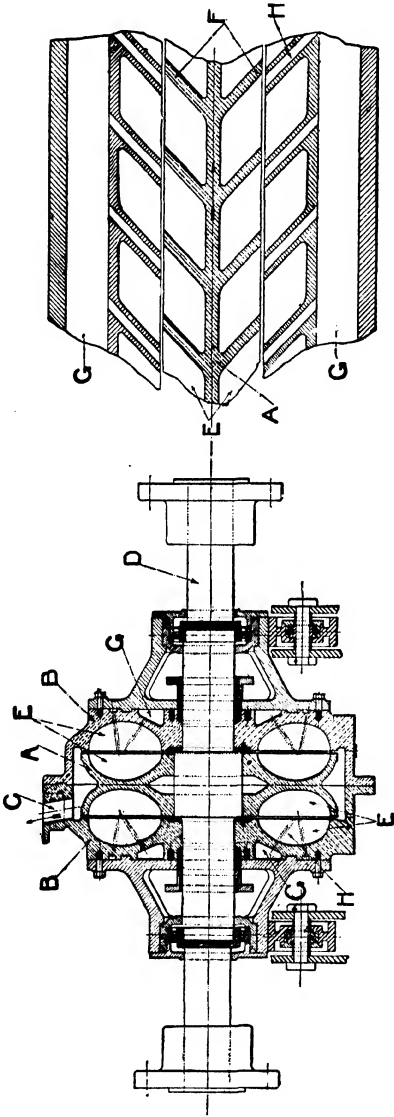
No. 536.—Sectional Elevation through Standard Froude Dynamometer.

A. Rotor pockets.　B. Casing pockets.　C. Cooling water outlet.　D. Shaft.　E. Water pockets.　F. Pocket division walls of rotor.　G. Water channels.　H. Holes in casing vanes for water admission to rotor pockets.

point near the shaft. Thus the pockets in the rotor and casing together form elliptical receptacles round which the water courses at high speed.

The resistance offered by the water to the motion of the rotor reacts on the casing, which tends to turn on its anti-friction roller supports. This tendency is counteracted by means of a lever arm, at the end of which balance weights are suspended, measuring the reaction.

Scientific Accuracy.

From the foregoing it will be seen that the forces resisting rotation of the dynamometer shaft may conveniently be divided into three main classes, namely :—

    (1) The hydraulic resistance created by the rotor.
    (2) The friction of the shaft bearings, which are usually of the roller type.
    (3) The friction of the glands.

It will be observed that every one of these reacts upon the casing, which, being free to swivel upon anti-friction rollers, transmits the whole of the forces to the weighing apparatus. Thus every force resisting rotation of the engine shaft is caused to react upon the weighing apparatus, which assures scientific accuracy.

Calculation of Power.

All Froude dynamometers have lever arms of such a length that the power absorbed under test can be very simply calculated by means of an easy formula, which is as follows :—

Where,   B.H.P. = The brake horse-power.
                W = Load at end of dynamometer arm in lbs.
                N = Revolutions per minute (by counter).
                K = Constant.

Then, $B.H.P. = \dfrac{W \times N}{K}$.

In the case of a machine built to British standards having an arm 5 ft. $3\frac{1}{10}$ in. long, K = 1000.*

For a metric machine having an arm 1432·4 mm. long, K = 500.

Water Supply.

It is important that the water supply should not be subject to violent fluctuations of pressure. If the dynamometer is of the reversible type, it ought to be fed through the medium of an over-head tank fitted with an equilibrium float valve to maintain a constant level. The pressure of the supply should usually be between 10 and 30 lbs. per sq. in.

         * 33000 ÷ 5·25 × 2 × 3·14 = 1000 = K.

Note.   5′ 3″ = 5·25′. Complete formula $= \dfrac{W \times L' \times 2 \times 3\cdot14 \times N}{33000}$.

   ,,   L′ = Length of lever arm in feet.
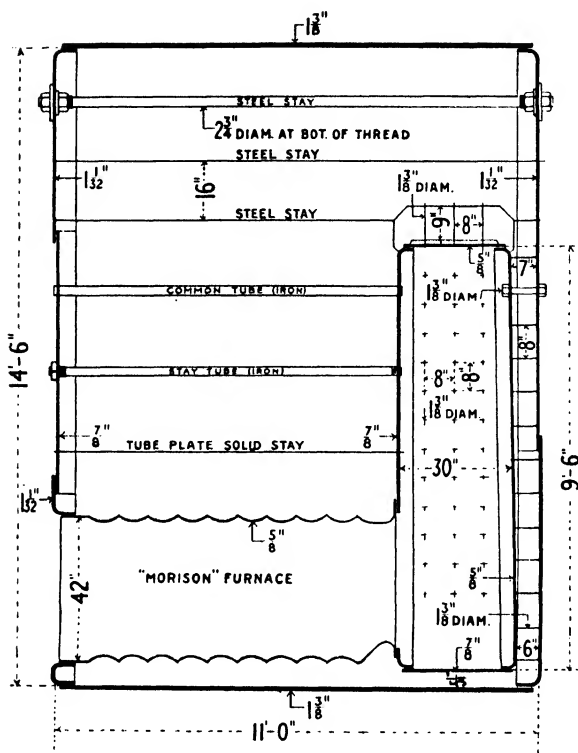
No. 538.—Sketch of Marine Boiler with Principal
Dimensions (Longitudinal Section).

Students preparing for the examination should practise drawing
the above sketch from memory, noting carefully the dimensions,
and the flanging of the plates, etc.

Notice that the furnace shown is of the Gourley-Stephen " Goose-
neck " withdrawable type, as the slightly elevated position of the
flange at the back allows of the furnace being canted up and with-
drawn from the front end opening, and replaced in the same manner.

Shell Thickness.—To find the required shell thickness if the pressure is to be 180 lbs. per square inch, joint 84 per cent., and Factor of Safety 4·6.

Rule, $28 \times 2240 \times T \times 2 \times \text{joint} = \text{Factor} \times D \text{ in.} \times \text{Safe Pressure.}$

Therefore,

$$T = \frac{\text{Factor} \times D \text{ in.} \times \text{Safe Pressure}}{28 \times 2240 \times 2 \times \text{joint}} = \frac{4 \cdot 6 \times 174 \text{ in.} \times 180}{28 \times 2240 \times 2 \times \cdot 84} = 1 \cdot 36 \text{ in., say } 1\tfrac{3}{8} \text{ in.}$$
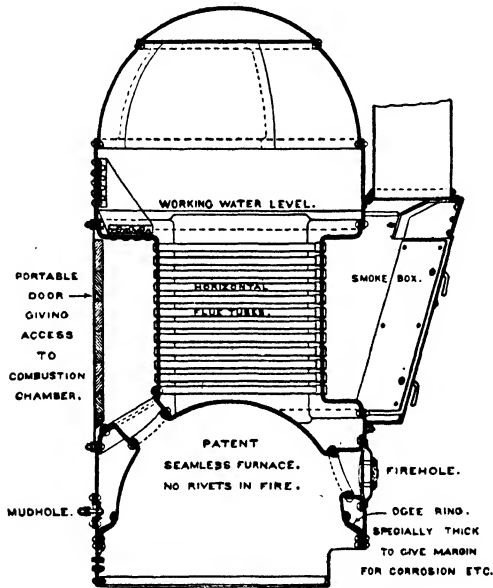
No. 539.—Cochran Boiler.

(Sketch suitable for Examination purposes.)

Diameter = 7 ft.
Height = 15 ft.
Heating surface = 600 sq. ft.

The boiler is fitted with horizontal smoke tubes, and when the smoke box doors are opened the tubes are accessible and can be easily cleaned when required: the smoke box is detachable.

The combustion chamber is situated at the back of the boiler and is lined with fire brick to promote combustion. The back plate, of light construction, is easily removable. The uptake consists of a flanged ring and is fitted with a flange externally only. The boiler does not require either stays or angles; the fire bars (coal firing) are supported on an angle-iron ring held in place by lugs. The furnace is seamless and no rivets are exposed to heat.

A ring riveted to the boiler shell connects to the furnace, the rivets being below the fire level.
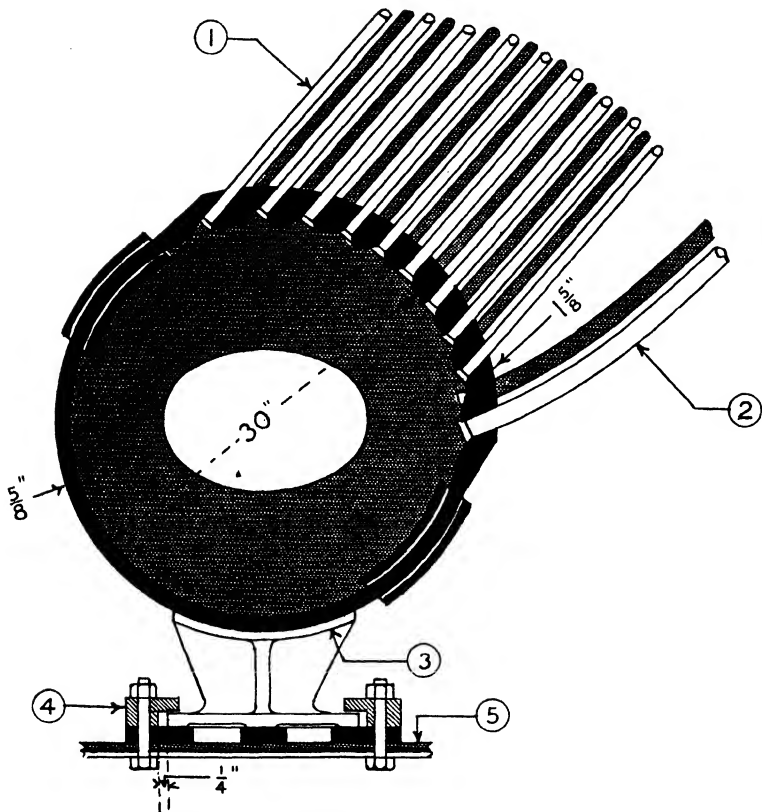
No. 540.—Water Drum of Yarrow Boiler.

(Also showing method of holding down and allowance for heat expansion.)

1, Tubes of $1\frac{7}{8}$ in. diameter.   3, Support bracket riveted to drum.

2, Tubes of $1\frac{1}{4}$ in. diameter.   4, Guide for sliding foot.

5, Tank top.

One end of the drum is bolted down solid to the tank top and the other end is free to expand, as shown above, the arrangement being similar to that adopted for turbine casings. The clearance of the sliding foot and guide is $\frac{1}{4}$ in. at the sides and $\frac{1}{16}$ in. on top.

At the fixed foot, side expansion is allowed for by having the bolt holes in the flange cut slightly oval in shape.

No. 541.—Vertical Type Donkey Boiler.
Pressure, 80 lbs. (gauge).

In the type of vertical auxiliary boiler shown above, four to six stays at about $1\frac{3}{4}$ in. diameter are fitted between the fire-box crown and boiler top, these stays acting to prevent either collapse of the fire-box crown or blowing out of the boiler end plate. The surfaces exposed to pressure not being truly spherical, require the support of stays. In the "Cochran" type auxiliary boiler (see pp. 815–845) the top of the boiler is truly spherical in construction, and this being so, stays become unnecessary.

Water Gauge.

In Fig. 1 the column shown is hollow cast, so that the water or the steam could pass through it : the test cocks show this.
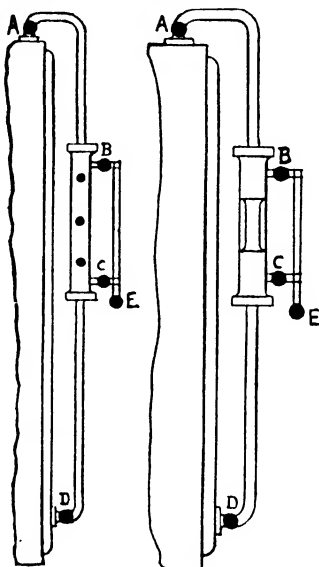
Fig. 1.   Fig. 2.

Note.—Open the drain and blow through, then close the drain and see if the water rises to the working level; if so, the connections are all clear ; if, however, no water shows, then either C or D is choked or the water is too low ; if, on the other hand, the glass shows full, then either A or B is choked or the water is too high.

To test if the steam connections are clear, shut cocks C and D, and have open cocks A, B, and the drain cock E. If steam blows through the cocks are clear.

To test if the water connections are clear, shut cocks A and B, and have open cocks D, C, and the drain cock E. If water blows through, the cocks are clear.

If cock A or cock B is choked, the glass will show full up. It will show the same if the pipe between A and B is choked.

If cock C or cock D is choked, the glass will tend to show a higher level owing to condensation, as the water will be shut off from the boiler altogether, but steam connection still open. If the drain is opened and shut, the glass will show empty as long as the cocks remain choked. The same thing will happen if the pipe between C and D is choked.

If the glass is showing full water, due to the cock A, or the cock B, having got choked, to test if it is A, shut D and B and blow through A, C, and E ; if steam blows out A is clear, if not, A is choked. To

test B, shut A and C and blow through D, B, and E ; if water blows out, B is clear, if not, B is choked.

If one of the two cocks C and D is choked, to find which it is, shut A and C and blow through D, B, and the drain E ; if water blows out, D is clear, if not, D is choked. To test C, shut D and B and blow through A, C, and E ; if steam blows out, C is clear, if not, C is choked.

Note.—In testing, before closing any of the cocks A, B, C, or D, it is advisable to first open the drain cock E, so that shocks on the pipes and glass may be avoided.

If cocks A and B are closed and the others left open and the glass blown through, if water comes, the water connections are clear : if, next, cocks C and D are closed and the glass blown through with cocks A and B open so that steam comes, the steam connections are clear; but if, on shutting the drain cock, no water shows in the glass, this proves that the water level in the boiler is too low, as it must be lower than the bottom nut of the gauge glass, otherwise the glass would show water.

If the gauge column is cast solid as shown in Fig. 2, then the water or steam could not pass through it, and to test the water and the steam, single shutting off on the column is sufficient.

To test the steam side, shut cock C, and leave cocks A, B, and the drain cock E open ; if steam blows out, the connection is clear. To test the water side, shut cock B and blow through cocks D, C, and the drain cock E ; if water blows out, the connection is clear.

The glass usually shows from $\frac{3}{4}$ to $1\frac{1}{2}$ in. less than the boiler level, the reason for this being that the water in the glass and pipe is colder than the water in the boiler, and, as water contracts in cooling, the level is lower in proportion.
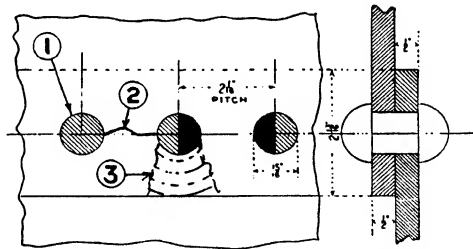
No. 542.—Single Riveting.

Strength of Joint.

$$\text{Seam} = \frac{(p-d) \times 100}{P} = \frac{(2\cdot0625 - \cdot9375) \times 100}{2\cdot0625} = 54\cdot5 \text{ per cent.}$$

$$\text{Rivets} = \frac{d^2 \times \cdot7854 \times \text{No.} \times 23 \times 100}{P \times T \times 28} = \frac{\cdot9375^2 \times \cdot7854 \times 1 \times 23 \times 100}{2\cdot0625 \times \cdot5 \times 28} = 54\cdot9 \text{ per cent.}$$

Joint strength (smaller) = 54.5 per cent. of solid plate.
Width of lap = ·9375 × 3 = 2·8125 in., or $2\frac{13}{16}$ in.

The joint may give out as follows :—

1. Rivets may shear.
2. Plate may crack between rivet holes.
3. The plate metal may be crushed out between the rivet holes and edge of plate.
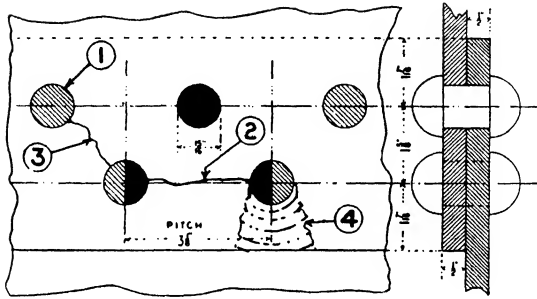
No. 543.—Double Riveting (Zigzag).

Diameter and Pitch of Rivets, etc.

Diameter of rivets $= 1\cdot2 \times \sqrt{\cdot5} = 1\cdot2 \times \cdot707 = \cdot848$ in., say $\frac{7}{8}$ in., or $\frac{16}{16}$ in.

Note.—In certain cases it is advisable to make the rivet fully the size found by the rule. In this case $\frac{16}{16}$ in. is fixed on as the diameter.

$$\text{Pitch} = \frac{100 \times \text{Rivet diameter}}{100 - \text{Joint}} = \frac{100 \times \cdot9375}{100 - 70} = 3\cdot125 \text{ in., or } 3\frac{1}{8} \text{ in.}$$

Centre of rivet to edge of plate $= \text{Rivet diameter} \times 1\cdot5 = \cdot9375 \times 1\cdot5 =$
$$1\cdot40625 \text{ in., or } 1\frac{7}{16} \text{ in.}$$
Distance between rivet rows (V) (Zigzag riveting).

RULE---

$$V = \frac{\sqrt{(11 \times p + 4 \times d) \times (p + 4 \times d)}}{10} = \frac{\sqrt{(11 \times 3\cdot125 + 4 \times \cdot9375) \times (3\cdot125 + 4 \times \cdot9375)}}{10} =$$
$$1\cdot61 \text{ in., say } 1\frac{5}{8} \text{ in., between rivet rows.}$$

Note.—The average strength of double riveted joints for thin plates = 70 per cent. of solid plate.

The joint may give out as follows :—
1. Rivets may shear.
2. Plate may crack between rivet holes lengthways.
3. Plate may crack between rivet holes diagonally.
4. The plate metal may be crushed out between rivet holes and edge of plate.
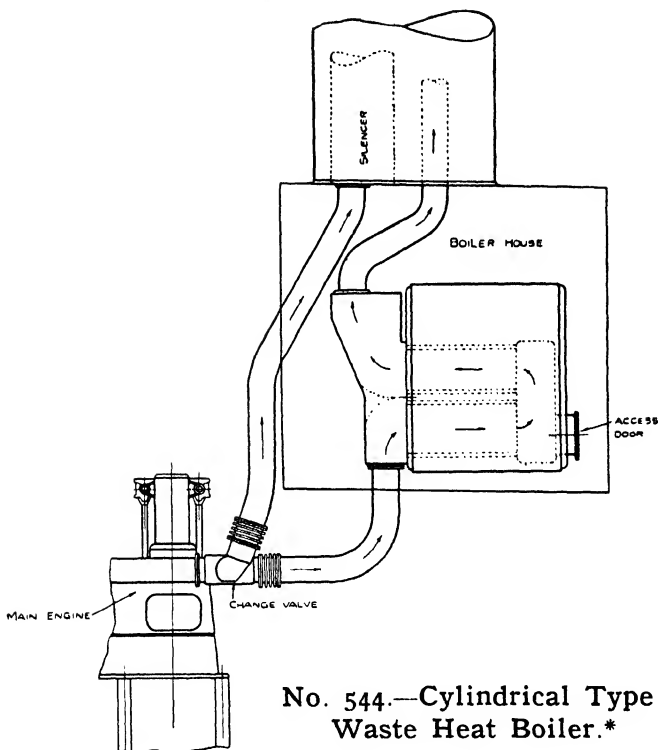
No. 544.—Cylindrical Type
Waste Heat Boiler.*

The wing furnaces are oil fired but the centre furnace space is fitted with tubes through which the exhaust gases from the engine pass and return by the upper tubes, thus giving a double flow effect. A change valve is provided so that the waste gases may be deflected direct to the atmosphere when required.

* Reproduced by courtesy of the Council of the Institute of Marine Engineers, London, from the paper entitled, " The Care and Maintenance of a Modern Diesel-Engined Tanker Fleet," read by H. S. Humphreys, Esq. (Vice-Chairman of Council), 14th January 1936.

"THERMOFEED" TYPE FEED WATER REGULATOR

Description;—

The " Thermofeed " mechanism consists of a non-collapsible float which, by means of toggle levers, operates a double-seated valve. The remainder of the " Thermofeed " can be regarded as a container in which the mechanism is housed, of ample strength to withstand the pressure within it.

90	Exhaust Pipe	
40	Top Nut	
62a	Z. Clip	
96	"S.E.A. Ring" Joint	
45	Hulburd Joint	
46	Double-seated Valve	
45	Hulburd Joint	
42	Steam Chest	
60	Valve Rod	
80	Adjustment Nut	
69	Retaining Plate	
34	Six : ⅜" Studs and Nuts	
95	Float Chamber Cover Joint	
92	Two "S.E.A. Rings" ₁⁄₁₆" × 1¼"	
65	Pin	
48	Top Narrow Toggle	
52	Bottom Wide Toggle	
68	Pin	
97	5" Float	

G.M. Union   100
S. Pipe   99
Three-way Valve   43
P.B. Nipple   41
Lock Nut   56
Column   58
Four: ¼" Studs and Nuts   35
Top Metal Header   70
Bottom Metal Header   72
Float Chamber Cover   78
Pin   64
Top Wide Toggle   50
Four: ⅜" Studs and Nuts   36
Pin   66
Bottom Narrow Toggle   54
Nameplate Screw   93
Nameplate   94
Float Chamber   76
Four: ⅜" Studs and Nuts   36

No. 545.—" Thermofeed " Feed Water Regulator.

The float, moving with the water level, operates the double-seated valve 46 by means of rod 60 through the toggle levers which reverse the direction of motion.

When the water level rises (and the float with it) the spindle of valve 46

is drawn downwards on to its upper seat, thereby permitting the passage of steam over the lower seat to operate the " Thermofeed " automatic regulating valve.

Alternatively, when the water level falls the float also moves downwards and the spindle of valve 46 is raised on to its lower seat, closing any further
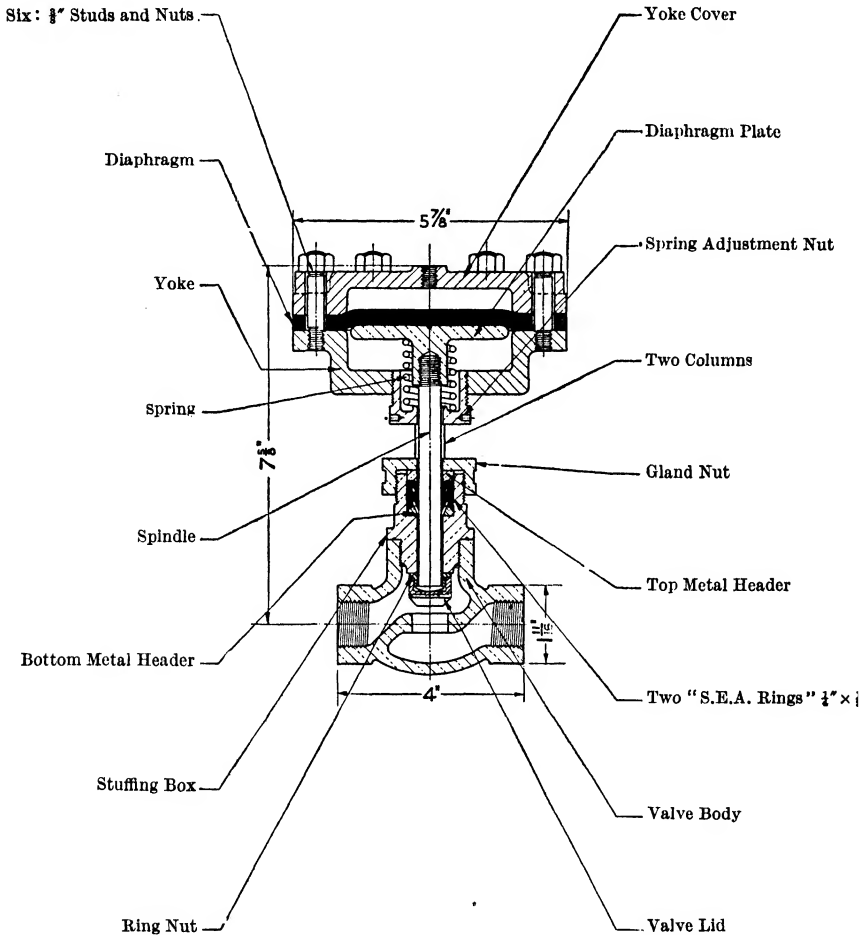
No. 546.—" Thermofeed " Control Valve
¾ In. Diameter Screwed.

exit of steam from the " Thermofeed," and at the same time releasing to atmosphere the steam which has already been permitted to operate the " Thermofeed " automatic regulating valve.

The whole of the controlling mechanism in the float chamber is attached to column 58, and can be raised or lowered by rotating adjustment nut 80, even

when under full pressure. Thus a fine adjustment of the water level can be made without moving the entire float chamber.

A three-way valve 43 is provided so that, if desired, the " Thermofeed " may be instantly put out of action. When on its upper seat, steam can pass to operate the " Thermofeed " automatic regulating valve and the installation is then in action; but when on its lower seat steam can no longer pass. Instead, any steam which has already passed through valve 43 is released to atmosphere through the port above the valve body, and the " Thermofeed " is then out of action. Valve 43 must never be left in a mid-way position.

To put the " Thermofeed " into commission, open slowly the steam stop
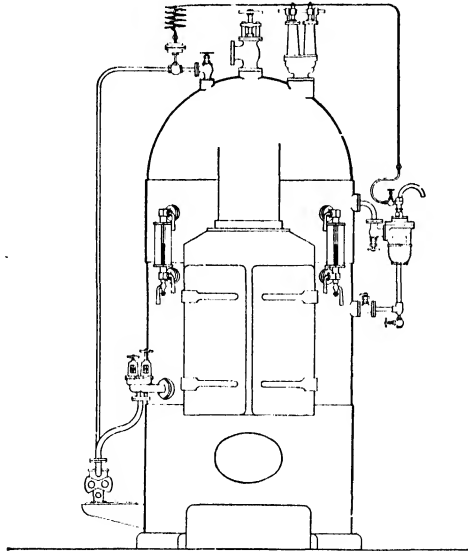
No. 547.—" Thermofeed " fitted on Cochrane
Type Auxiliary Vertical Boiler.

valve and then the water stop valve which isolate the float chamber from the boiler.

Valve 43 should be opened and closed to its full extent a few times to ensure that all traces of air are excluded from the ¼-in. bore copper pipe which connects the " Thermofeed " and the automatic regulating valve, and it should be left in the " open " position.

The " Thermofeed " is then free to operate and will continue to do so as long as there is sufficient pressure in the boiler.

An adjustment is provided to vary slightly the precise level at which the " Thermofeed " will maintain the water level in the boiler. This adjustment can be performed even when the boiler is steaming, but it is advisable first to close the water and steam valves to isolate the float chamber from the boiler. It is only necessary to slacken retaining plate 69 and to rotate adjustment nut 80, which causes column 58, and with it the whole mechanism, to be raised or

lowered. When the desired level has been established, retaining plate 69 should be firmly secured and the steam and water stop valves again opened.

In service it is a good plan to make use of the blow-down valve and so to ensure that sediment and other foreign matter does not accumulate in the steam and water connections between the float chamber and the boiler, or even in the float chamber itself. Especially is this advisable where the boiler feed water is at all impure.

It will be noted that when the float falls with low water level, steam is shut off from the control valve diaphragm, and the feed pump then functions to deliver feed water into the boiler. When, however, the float rises with a higher water level, steam is admitted to above the diaphragm plate of the control valve (No. 546) so that the plate is depressed and, overcoming the spring resistance below, closes the steam supply valve of the feed pump, and the pump then stops working.

With Clarkson boilers rotary type feed pumps are often fitted.

For electrically driven feed pumps the " Thermofeed " is arranged to actuate a control diaphragm-operated electric switch, which can be inserted in the main pump motor circuit. When the diaphragm plate is depressed the switch contact is broken and the pump motor stops running.

Fires from Oil Gases.

Fire damp (marsh gas) is explosive when mixed with certain quantities of atmospheric air and in contact with a naked light.

The most violent explosion occurs when the proportion of air to gas by volume is as 9.5 is to 1. If the air supply is less than this the explosion will be less violent, and the same holds good when the air supply is in excess of the proportion stated. If the air supply is unlimited (such as in the open air), the gas may only ignite and burn in place of exploding. The danger of explosion is therefore greatest in confined spaces, such as tanks, when the air supply is limited in quantity. It should be noted that before combustion of any kind can be brought about, the presence of atmospheric oxygen is necessary.

When a serious fire breaks out in, say, the double-bottom oil tanks, the application of a fire-fighting substance, such as " Petrofoam" for example, results in the deposit of CO_2 in the condition of a spongy solid, and this being a non-supporter of combustion prevents the admission of oxygen, which, as already explained, strongly induces combustion to take place. If the admission of atmospheric air to the tank could be absolutely shut off, the fire would in due time die out through want of oxygen.

DISCHARGE   SUCTION

SECTION AT B.B. OF
SECOND STAGE GEARS
LOOKING IN DIRECTION
OF ARROW 'C'

SECTION AT A.A. OF
FIRST STAGE GEARS
LOOKING IN DIRECTION
OF ARROW 'C'

No. 548.—The Weir " Pyro " Two-stage Geared Rotary
Type Oil Fuel Pressure Pump.

The oil flows in through the suction branch, then through port D to the
first-stage wheels, discharging through port E to the second-stage wheels,
and thence to discharge branch through port F.

The pump is usually motor driven with chain transmission gear.

The arrows show the rotational direction of the wheels.

Regulation of Pump Output.

With A.C. motor drive by means of a by-pass valve ;

with D.C. motor drive by means of shunt field regulation ;

and by by-passing, in addition, if required.

For oil of ·93 specific gravity and possessing a viscosity of 2000 seconds
Redwood No. 1, against a discharge pressure of 150 lbs. $\boxed{n}$, the capacity
and power of a typical pump work out as follows :—

$$
\begin{aligned}
\text{Gallons per hour} &= 1630. \\
\text{Revolutions} &= 960. \\
\text{H.P.} &= 7. \\
\text{Diameter of inlet branch} &= 4 \text{ in.} \\
\text{,,} \quad \text{of outlet branch} &= 3 \text{ ,,}
\end{aligned}
$$

$$
\text{Efficiency} = \left(\frac{1630 \times 10 \times \cdot 93 \times 2 \cdot 305 \times 150}{7 \times 33000 \times 60} \right) \times 100 \ \% = 38 \ \% \text{ nearly.}
$$

No. 549.—Davy Safety Lamp.

1. Oil well.
2. Air supply to burner.
3. Wick.
4. Wick regulation screw.
5. Circular glass window.
6. Copper gauze mesh envelope.

Davy Safety Lamp.

This type of lamp is employed for the detection of explosive gases, fire damp (Marsh Gas) in pumped-out oil tanks, or choke damp (CO_2 gas) in ballast tanks. The copper gauze envelope which surrounds the lamp quickly absorbs the low heat of the wick flame, which is thus dissipated before it can pass from the inside to the outside of the lamp and cause an explosion.

It should, however, be noted, that the lamp requires careful handling, that is, it must not be swung about freely, but should be held as steadily as possible when being used for the detection of explosive gases.

If the proportion of marsh gas (fire damp) present in the atmosphere exceeds 3 per cent., a faint and triangular shaped blue-coloured cap appears about the flame.

Testing.

1. If the flame burns clear the atmosphere is free from foul air or dangerous gas.

2. If the flame develops a faint blue cap above, then fire damp is present and danger of explosion exists.

3. If the lamp burns black or goes out, CO_2 gas (fatal to life) is present.

Indicator Diagrams.

No. 550.—Combined Diagram and Draw Card.

(Four-cycle Blast Injection Engine.)

The compression pressure is equal to 470 lbs. per sq. in. and the firing pressure 600 lbs. per sq. in., this latter being in excess of that usually considered the best practice.

Exhaust temperature = 820° F.

Blast air pressure = 825 lbs. $\boxed{''}$.

Revolutions = 106.

Diagrams Nos. 550, 551, and 552 are of interest as all are taken off the same engine and represent the following :—

No. 550, ordinary full-scale diagram of $\frac{1}{360}$ scale.

No. 551, medium spring diagram of $\frac{1}{180}$ scale which registers exhaust pressures and air suction pressure. This diagram shows evidence of late exhaust opening.

No. 552, an ordinary low spring diagram of $\frac{1}{40}$ scale and which registers accurately the low pressure positions as marked. The marking 6·2 lbs. represents the back pressure and the air suction pressure combined, say, 4 lbs. back pressure and — 2·2 lbs. suction air pressure.
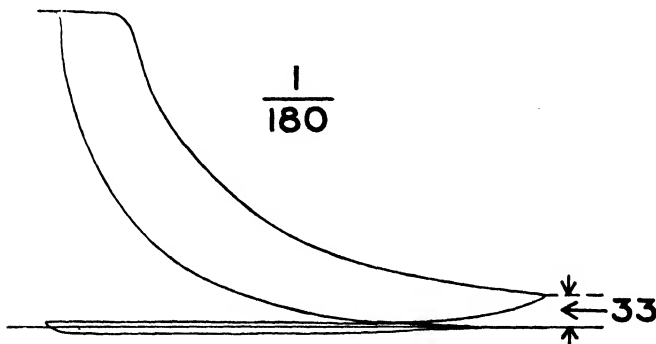
No. 551.—Medium Spring Diagram.

(Four-cycle Blast Injection Engine.)

$$\frac{1}{40}$$

33

A.L.

6·2
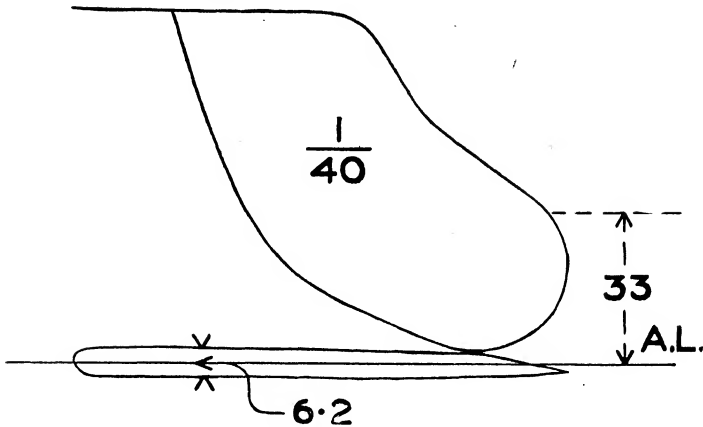
No. 552.—Low Spring Diagram.

(Four-cycle Blast Injection Engine.)

The diagram shows clearly the exhaust opening, the back pressure, and the air suction pressure, the latter being below atmospheric pressure (about — 2 lbs.).

Exhaust temperature = 820° F.

Blast air pressure = 825 lbs. $\boxed{''}$.

Revolutions = 106.

$$\frac{1}{360}$$

630

450

A.L.
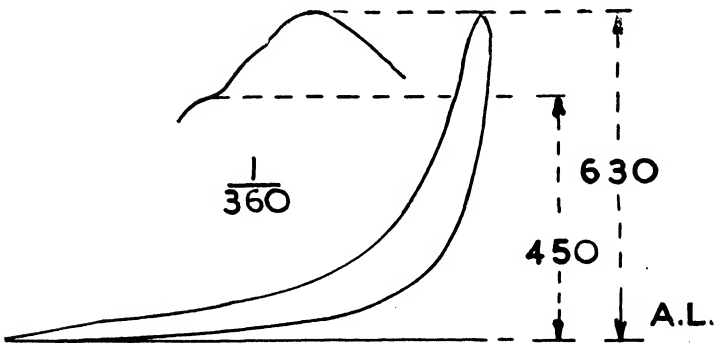
No. 553.—Diagram and Draw Card.

(From the top end of a D.A. solid injection two-cycle engine fitted with exhaust piston valves top and bottom.)

The compression pressure is of normal value, but the firing pressure is high.

The average M.I.P. worked out to about 6·2 atmospheres or, say, 94·5 lbs. per sq. in.

The bottom diagrams gave a lower result, or only about 5·3 atmospheres, say, 80·5 lbs. per sq. in. with a similar firing pressure. The piston rod displacement at the lower end reducing the effective piston area, chiefly accounts for the difference in M.I.P. recorded. Two fuel valves are provided at either end of the cylinder.
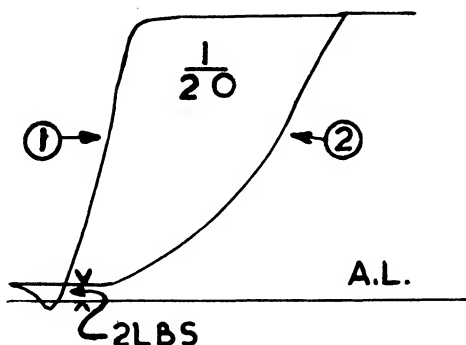
No. 554.—Low Spring Diagram.

(From top of D.A. solid injection two-cycle engine fitted with exhaust piston valves top and bottom.)

1, Exhaust.
2, Compression.

It will be noted that the exhaust pressure drops to slightly below the atmosphere, and when the scavenge air ports are uncovered by the piston the pressure then rises to 2 lbs. above the atmospheric pressure.

The bottom diagram is similar to that of the top.

Exhaust gas temperature $= 270°$ C, or, $\left(270° \times \dfrac{9}{5}\right) + 32° = 518°$ F.
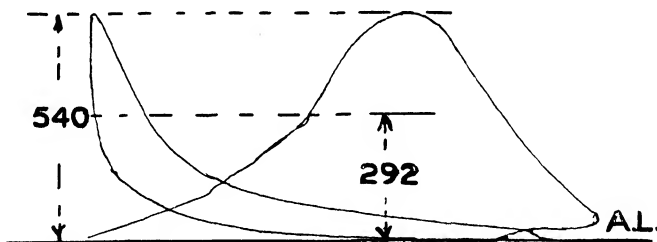
No. 555.—Combined Diagram and Draw Card.

(From Doxford Opposed Piston Solid Injection Two-cycle Engine. Draw card described by special cam.)

It will be noted that consistent with usual Doxford practice the compression pressure is low, being only 292 lbs. per sq. in. This pressure is found sufficient for the reason that the piston faces, of cast steel, retain heat and act in a modified form as a hot-plate or hot-bulb engine.

Data.

Fuel pressure = 6000 lbs. $\boxed{''}$.
Fuel oil temperature = 95° F. (heated).
Exhaust temperature = 640° F.
Piston cooling water outlet = 160° F.

Jacket cooling outlet = 136° F.
Engine revolutions = 112.
M.I.P. = 79·6 lbs. $\boxed{''}$.
I.H.P. (total) = 1821.
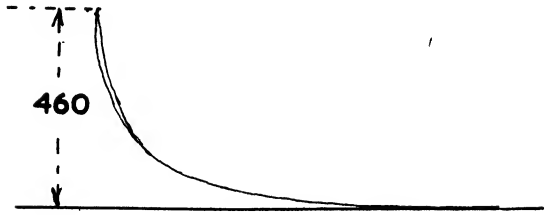
No. 556.—Compression and Re-expansion Diagram.

(Four-cycle Blast Injection Engine.)

This diagram was taken with the fuel shut off.

It will be noted that during expansion the pressure falls slightly after the beginning of the down stroke and later joins the compression curve, this being due to loss of compression heat to the cooling water.

Exhaust temperature = 820° F.

Blast air pressure = 825 lbs. ☐.

Revolutions = 106.
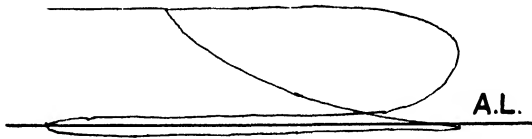
No. 557.—Low Spring Diagram.

(From Four-cycle Blast Injection Engine).

It will be noted that the air suction pressure is below that of the atmosphere, and may be equal to about 12 lbs. absolute per sq. in.
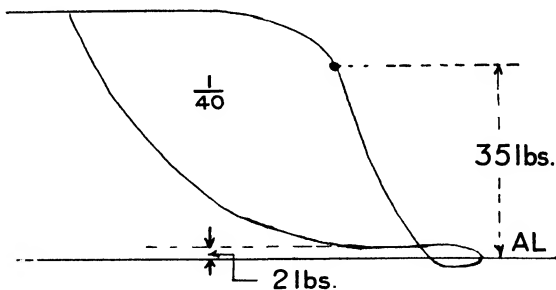
No. 558.—Light Spring Diagram ($\frac{1}{40}$)

(From Two-cycle Engine with valve-controlled scavenge air ports.)

Scavenge air pressure = 2 lbs.
Exhaust ports uncovered, 40° B.B.C.
    ,,   ,,   closed, 40° A.B.C.
Scavenge air ports uncovered, 30° B.B.C.
    ,,   ,,   closed, 55° A.B.C.

It should be noted that both the exhaust and scavenge actions occur within 95° when passing the bottom centre, or exhaust opens 40° B.B.C. and scavenge ports close 55° A.T.C., then 40° + 55° = 95°.

Exhaust pressure = 35 lbs. gauge.

When the exhaust ports are uncovered the jet velocity effect of the escaping gases set up a momentary vacuum in the cylinder, which explains why the exhaust pressure line falls below that of the atmosphere during a short period of the down strokes. The admission of the scavenge air pressure of 2 lbs. gauge is shown by the increase in back pressure followed by compression.

Fires in Scavenge Air Trunks of 2-Cycle S.A. and D.A. Engines.

—Fires sometimes break out in the scavenge air trunks, and may lead to serious trouble, and constitute a disturbing factor to the engine-room staff. The cause is evidently due to accumulations of lubricating oil which has been blown through the scavenge air ports of the cylinder liner, and which adheres to the casing plates of the air trunk and becomes overheated.

If hot gases or sparks pass the piston rings, ignition may take place, leading up to a fire. The only remedy for this trouble so far suggested is (*a*) to reduce the piston lubrication quantity to a minimum and to ensure that the piston rings are maintained in a perfectly gas-tight condition.

It has also been suggested (*b*) to alter the position of the piston rings nearest the scavenge air ports, that is, the lower rings of the upper piston and the upper rings of the lower piston to be brought nearer to the scavenge air port openings. Increasing the piston-ring oil-film thickness has also been tried (*c*) as a remedy against gas leakage.
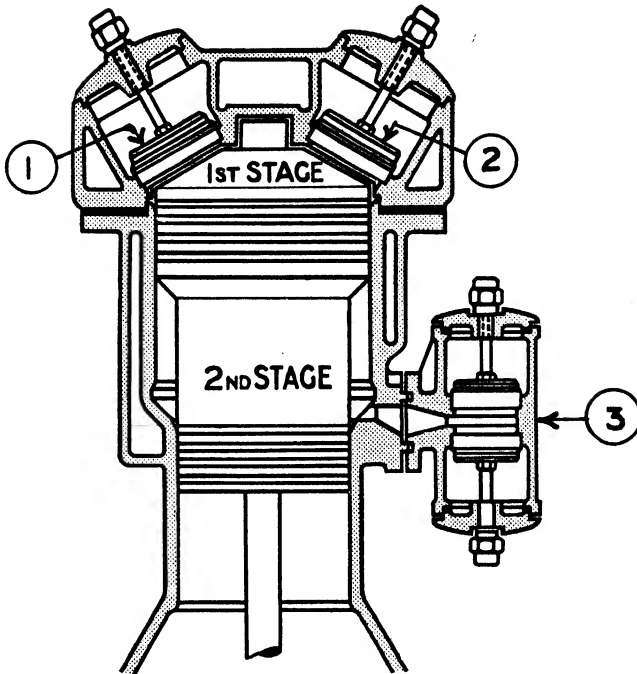
No. 559.—Two Stage Air Compressor.*

1, 1st stage (L.P.) suction valve.
2, 1st stage (L.P.) delivery valve.
3, 2nd stage suction and delivery valve chest.

This type of compressor is sometimes used in solid injection engines for the production of starting air at, say, 350 to 400 lbs. pressure per square inch.

Data.

> 1st stage suction air pressure = 12 lbs. absolute.
> 1st stage delivery air pressure = 70 lbs. absolute.
> 2nd stage suction air pressure = 55 lbs. absolute.
> 2nd stage delivery air pressure = 400 lbs. absolute.

The temperature after compression and before cooling in either stage ranges between 270° and 290° F., and after cooling drops to 95° or 110° F.

The piston clearance is kept down to minimum valve, say, $\frac{1}{16}$ in. for the 1st stage.

* Reproduced by courtesy of the Institute of Marine Engineers from a paper by J. Hendry, entitled, " Air and Gas Compressors."

"WEIR" TYPE AIR COMPRESSOR
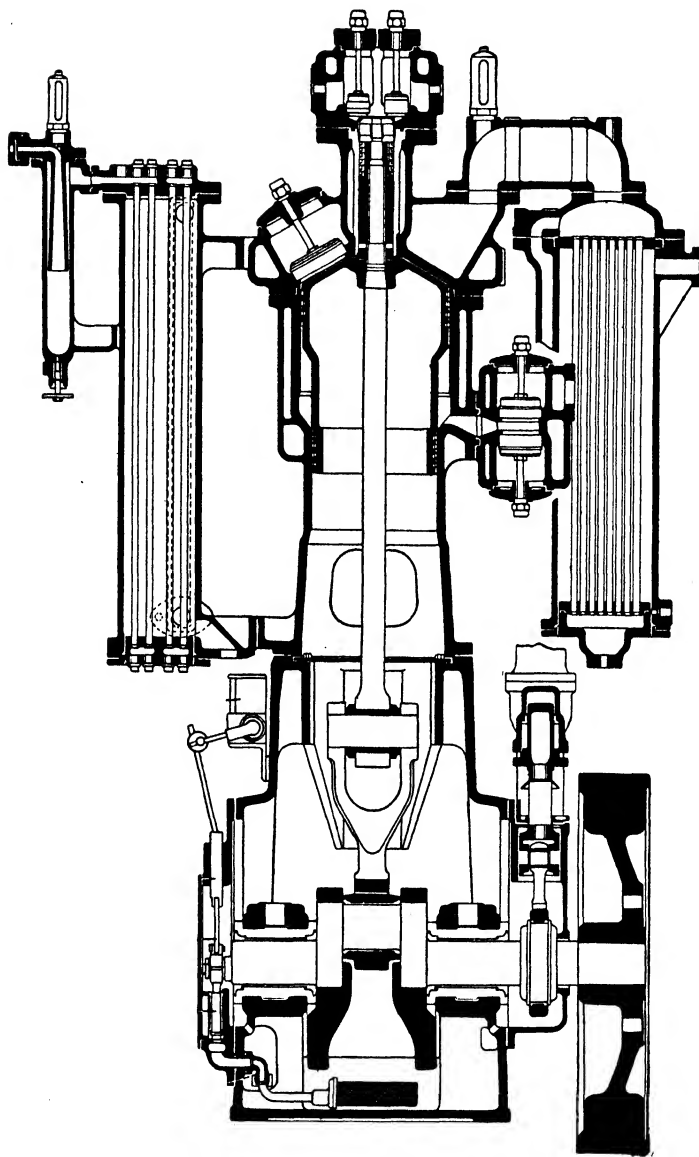
No. 560.—Standard "Weir" Type Three Stage Air Compressor.

Final compression pressure = 600 lbs. per sq. in.

Capacity = 100 cub. ft. free air per min. at 350 revs. per min.

This machine is often fitted in Doxford engined vessels for the supply of starting air at 600 lbs. pressure.

Data.

11½ in. × 6½ in. Three stage Compressor, 350 revs. per min., circulating water temperature, 46° F.

		Lbs. per Sq. In.	Outlet from Cylinder.	Outlet from Cooler.
1st stage pressure	- -	40	231° F.	96° F.
2nd ,, ,,	- -	225	228° F.	96° F.
3rd ,, ,,	- -	600	153° F.	77° F.

Assuming a receiver capacity of 150 cub. ft., the time taken for a machine of this size to pump up to 600 lbs. per sq. in. would be approx. 61 minutes.

Description.

On the downward stroke the air is drawn through a special strainer grid to the first stage suction valves, and on the return stroke is compressed to the first stage pressure and delivered through the first stage discharge valves. From here the air passes through the bridge connection to the first stage cooler and thence to the second stage suction valve, which open automatically during the upward stroke. Again, on the downward stroke the air is compressed to the second stage pressure and delivered through the second stage discharge valves and second stage cooler to the third stage suction valves, which open automatically on the downward stroke; on the upward stroke the air is compressed to the required final pressure and delivered through the third stage discharge valves. The air now passes through the third stage or after cooler to the final oil and water separator from which it emerges in a suitable condition for the required duty.

The air cylinders are made in hard close-grained cast iron, and carefully bored to the close limits required for air compressor efficiency. The valve boxes and cylinders are water jacketed, and the third stage cylinder is fitted with a special cast-iron liner. The first stage valve box is conical in shape, which reduces the cylinder clearance to a minimum and gives a high volumetric efficiency. The second stage valve box is of vertical type, constructed of cast iron, and readily detachable from the cylinder.

The third stage valve box is made in high tensile gun-metal.

Pistons.

The first and second stage piston is of the differential type, made in close-grained cast iron and fitted with a sufficient number of spring rings in cast iron. It is fitted to the piston rod on a taper and secured by a special gun-metal castellated nut.

The piston body is in cast iron, with cast-iron carrier rings and spring rings of the same material. The piston is fitted to the rod on a taper and the rings are held in place on the piston with a washer and locked nut.
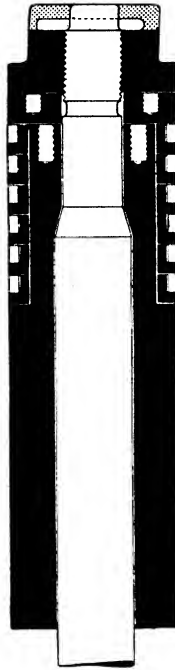
No. 561.—Third Stage (H.P.) Piston.

(Standard " Weir " Three Stage Air Compressor.)
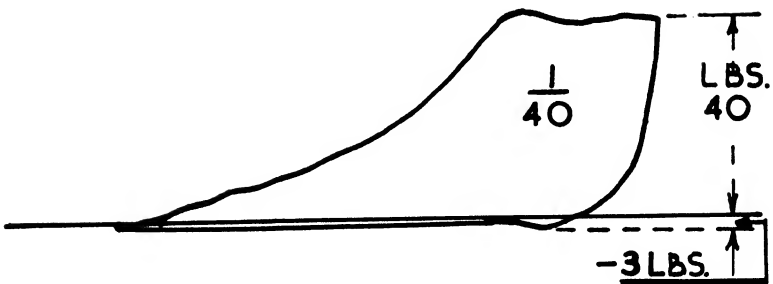
No. 562.—L.P. Stage Compressor Diagram.

(" Weir " Three Stage Compressor.)

It will be noted that the suction air pressure is equal to —3 lbs., or about
12 lbs. absolute.

LBS.
225

$\overline{200}$

25LBS.
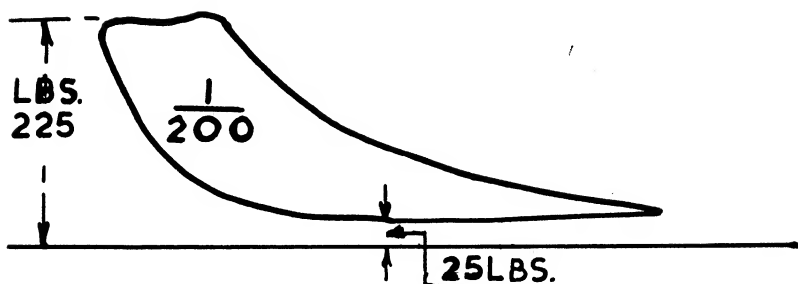
No. 563.—M.P. Stage Compressor Diagram.

("Weir" Three Stage Compressor.)

The excessive expansion curve (on left) is, in this case, due to the unavoidable clearance volume due to the position of the suction and delivery valve box at this stage.

$\overline{360}$

LBS.
600

200 LBS.
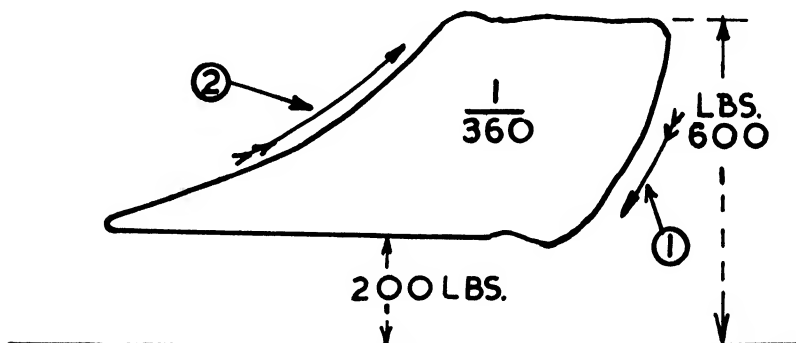
No. 564.—H.P. Stage Compressor Diagram.

("Weir" Three Stage Compressor.)

1, Expansion of clearance volume air.
2, Compression curve of air.

Note.—The arrows indicate the travel movement of the indicator pencil in describing the diagram.

It will be noted that the delivery compression pressure of the L.P. stage, 40 lbs., drops to 25 lbs. suction in the M.P. stage. Also that the M.P. delivery pressure of 225 lbs. drops to 200 lbs. in the H.P. suction. These respective drops are due to reduction in volume and expansion of the air after cooling.

It will be noted that compared with usual Diesel engine compressor practice the compression temperatures before cooling are low. This is accounted for partly by the low sea-water temperature (46° F.) and by the final maximum pressure being only 600 lbs. per sq. in. against, say, 950 or 1000 lbs. per sq. in. In the latter case the temperature before cooling might have been somewhere in the region of 300° F.
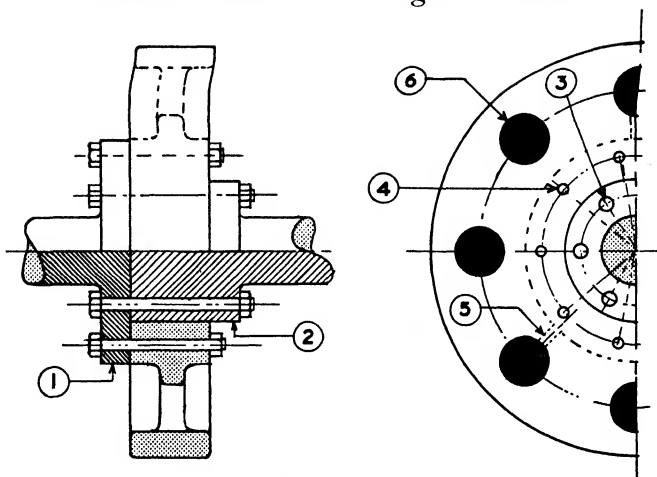
No. 565.—Flywheel.

This type of flywheel is sometimes fitted on two-cycle engines of the Doxford opposed piston type.

1, Flange on main shaft.
2, Heavy flange on crank shaft.
3, Six strong bolts.
4, Nine lighter bolts.
5, Gaps (three) cut in wheel to allow for relief of stresses set up.
6, Holes through wheel.

In this case the flywheel is of solid construction.
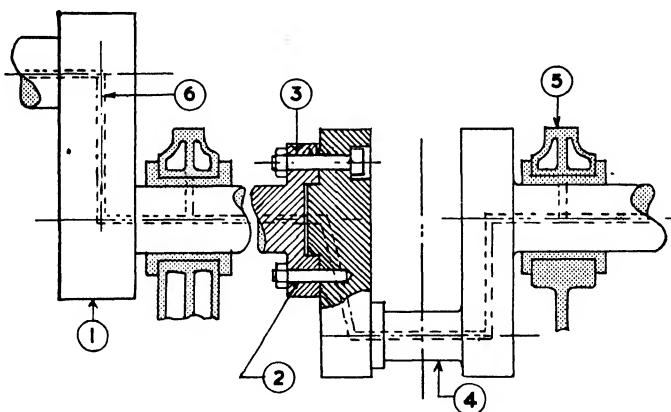
No. 566.—Compressor Crank Drive.

The three-stage blast air compressor is usually driven from the forward or after end of the crankshaft. The stroke of the compressor is less than that of the main engine. The web of the compressor crank next the main engine crank web is recessed into same and bolted as shown, the heads of the bolts being recessed into the cheek of the web. At the position of the compressor crankpin two studs are substituted in place of two bolts.

1, Main shaft crank web.
2, Two studs.
3, Four bolts with heads recessed into web.
4, Compressor crankpin.
5, Compressor bearing.
6, Forced lubrication system.

SECTION
"A-B"

CHARGING ∞ DRAIN
VALVE FOR DIESEL
ENGINE AIR BOTTLES
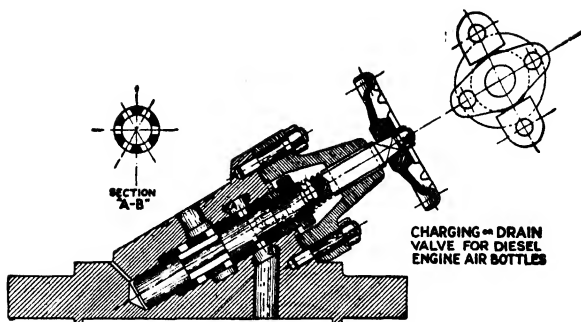
No. 567.

The above illustration describes the latest type of Klinger's seatless piston valve adopted for the air bottles on Diesel engines.

Practical experience has shown that the seatless piston valve is exceedingly reliable for very high pressures. As a matter of fact, valves have already been constructed and are in use giving entire satisfaction under hydraulic pressures of 8500 lbs. per sq. in.

Another advantage of the Klinger valve is the fact that by means of an indicator which the makers are supplying, it is possible to adjust the flow in such a manner to ensure that only just the required amount of air passes through the valve.

It may be mentioned that one of the largest motor ships of the British mercantile fleet is fitted with Klinger valves in such places where other types of valves did not give complete satisfaction.
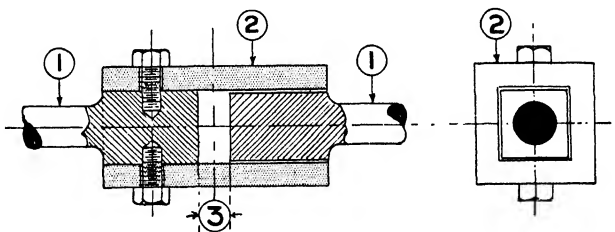
No. 568.—Expansion Coupling for Steering Gear Transmission Shaft from Steering Wheel.

As shown in the sketch the transmission shaft from steering wheel to engine control valve is fitted in two sections which are coupled up by means of the expansion box fitting. The end of one section is secured by pins to the box and the other section is free, so that the clearance shown allows for the effects of heat expansion in either direction.

1, Transmission shaft with squared ends.
2, Box for expansion movement.
3, Allowance for expansion.

NICKEL CAST IRON
SCREWED PLUG
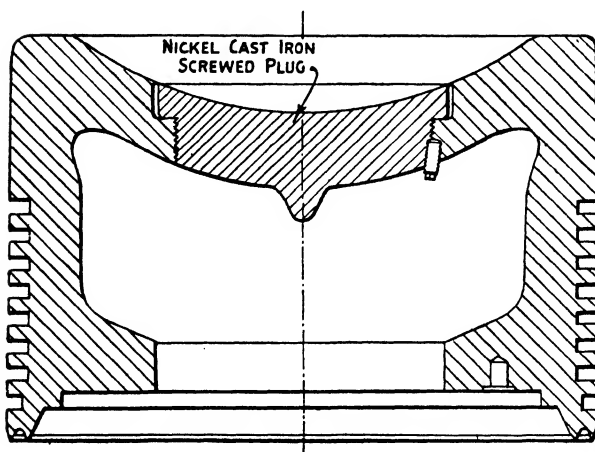
No. 569.—Nickel Cast Iron Screwed Plug sometimes
Fitted in 4-Cycle Engines.*

If cracking occurs this plug may be removed and replaced without the piston requiring to be scrapped. A locating screw dowel is fitted either below, as shown, or above.

PISTON

CYLINDER
LINER
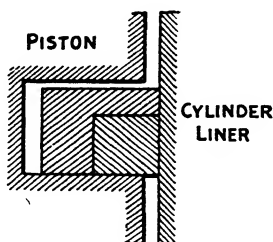
No. 570.—Double Seal Piston Rings.*

This type of double ring is sometimes used in piston where excessive liner wear has taken place.

* Reproduced by courtesy of the Council of the Institute of Marine Engineers, London, from the paper entitled "The Care and Maintenance of a Modern Diesel-Engined Tanker Fleet," read by H. S. Humphreys, Esq. (Vice-Chairman of Council), 14th January 1936.

No. 571.

Renold Bush Roller Chain Camshaft Drive for 4-Cycle Engines.

1, Shaft wheel.
2, Guide wheel.
3, Jockey wheel.
4, Pivot centre.
5, Jockey adjustment screw.
6, Gear wheel to camshaft wheel.
7, Camshaft.
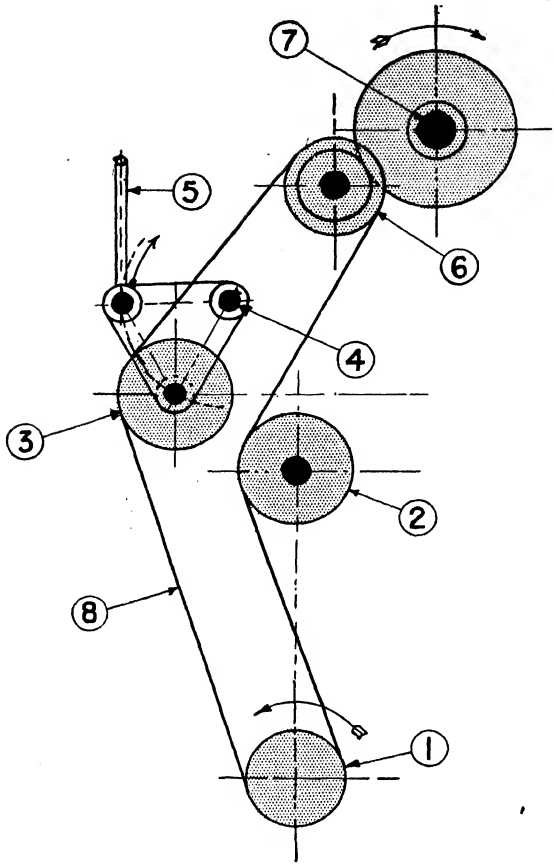
No. 572.

Details of Link (with Dimensions).

1, Roller.
2, Riveted pin.
3, Link.

$3\frac{7}{8}$

3

$1\frac{1}{8}$" 2"

1·81"
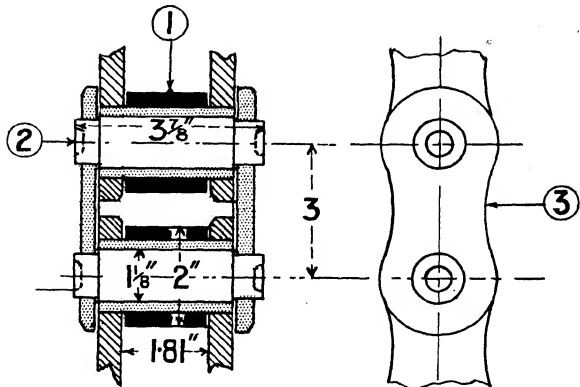
Renold Bush Roller Chain (3-in. pitch) for Camshaft Drive.

Slack may develop due to elongation produced by the severe tensile pull on the link joints, also by slight roller wear.

After sustained periods of service it may become necessary to remove one link length of the chain to take out the slack. Slackness of the chain may result in wear of the sprocket-wheel teeth.
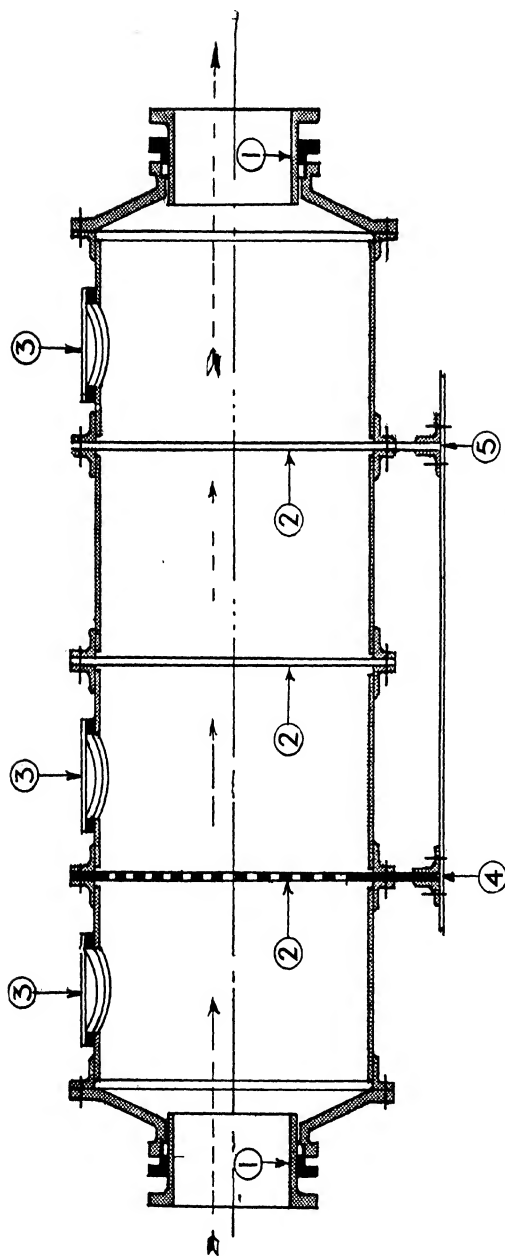
No. 573.—Exhaust Gas Silencer.

1, 1, Expansion joints.
2, 2, 2, Perforated plates with $1\frac{1}{8}$ in. diameter holes.
3, 3, 3, Access doors.
4,   Fixed foot.
5,   Expansion foot, with oval bolt holes.

The silencer shown may be placed horizontally, or, if contained in the funnel, vertically.

Drains are sometimes fitted to extract any moisture which may collect.

In some cases the silencer is supported on springs to allow of expansion.
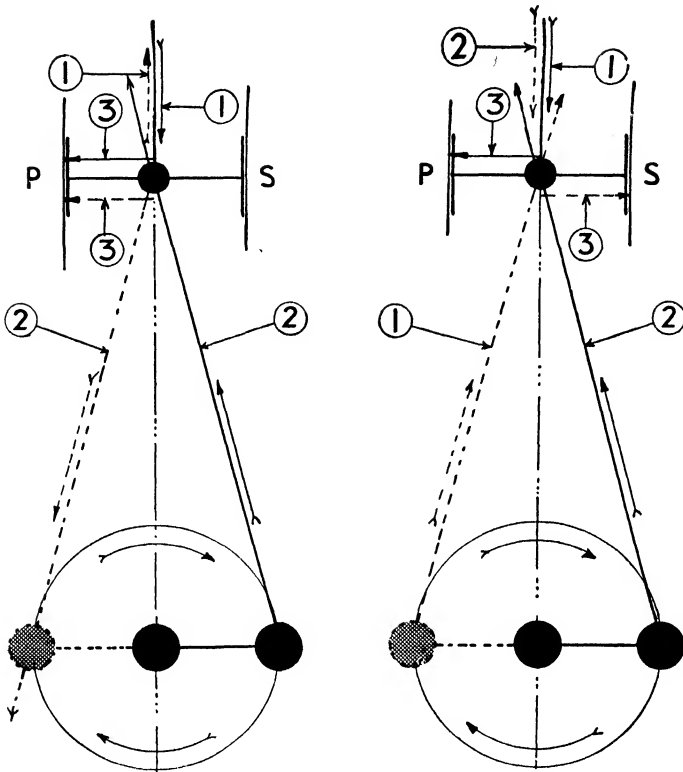
No. 574.—Diagram of Pressure on Guides.
(Steam and Diesel Engines.)

Full lines show down stroke.
Dotted lines show up stroke.
Left-hand view represents steam practice, and right-hand view single-acting Diesel engine practice.

1, Force.   2, Resistance.
3, Resultant force on guide.

From the above it will be evident that in the case of double-acting engines (steam or Diesel) the pressure resultant will act on the port guide for both up and down strokes with a right-hand propeller; also, that in the case of single-acting Diesel engines the pressure alternates between the two guides, being on the port guide during the firing (down) stroke and on the starboard guide (up) on the compression stroke.

NOTE.—It may be pointed out that in steam practice the guide pressure is reversed momentarily when the engine is turning the centres, top and bottom, this change occurring when the compression pressure on one side exceeds the driving pressure on the other side. It therefore follows that even a non-reversible engine requires to be fitted with double guides.

"Contra" Propeller.

A ship's propeller causes the wake stream lines to move in two directions, the axial movement being that which drives the ship and the tangential movement that which causes the propeller stream to twist and which represents loss of power.

"Star" contra propellers have been designed to eliminate this loss and utilise the stream flow towards increased propeller efficiency.
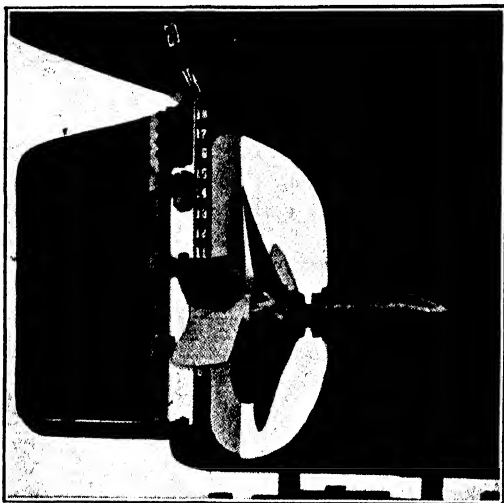
No. 575.—"Star" Contra Propeller (Fitted Aft).

If the "star" propeller is arranged as shown above, the tangential acceleration of the propeller stream is then converted into axial acceleration as the stream lines are diverted longitudinally as shown.

The advantages claimed for this improved propeller arrangement include the following :—

1. Increase of speed with same I.H.P.; or, same speed with reduced I.H.P.

2. Improved steering of ship.

3. Protection to main propeller from wreckage, etc.

4. Reduced running costs of vessel.
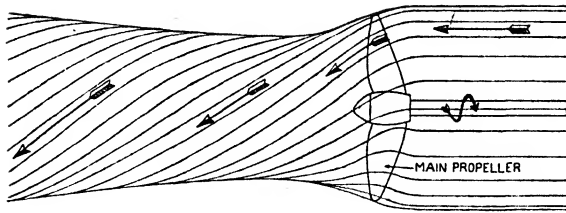
PROPELLER WITHOUT CONTRA PROPELLER.

MAIN PROPELLER

CONTRA PROPELLER
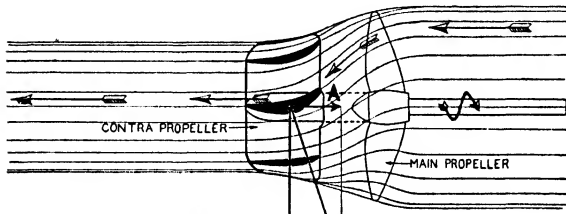
MAIN PROPELLER

PROPELLER WITH CONTRA PROPELLER.

T   R

No. 576.—Diagram showing Flow of Water without and with a Contra Propeller.

A, Axial thrust due to contra propeller.
R, Resultant reaction on propeller.
T, Tangential or rotational force.

Stern Brackets.
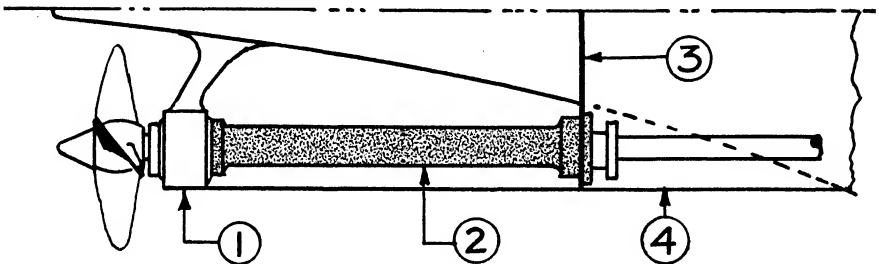
No. 577.—View of Starboard Stern Bracket and Stern Tube of Twin-Screw Steamer.

1, Stern bracket eye-boss.
2, Stern tube.
3, Bulkhead.

4, Plating of hull which envelops, and is secured to the stern bracket by means of screwed and riveted studs.
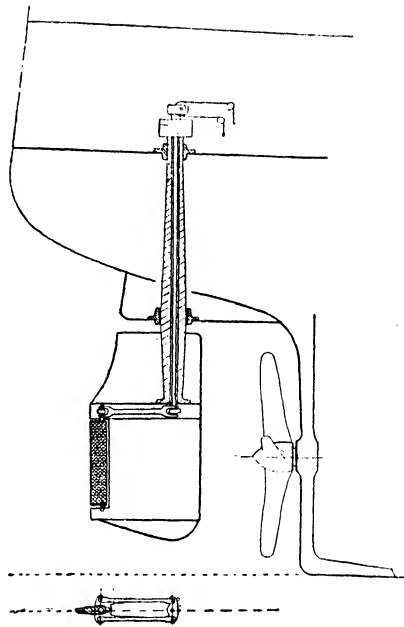
No. 578.—Flettner Type Rudder.

A small auxiliary rudder (shown shaded) is hinged to the after-part of the main rudder, and by means of suitable hand gear the small rudder can be operated to port or starboard, and the water thrust acting on its blade surface results in the main rudder being moved over to the opposite side. The auxiliary rudder is thus intended to operate the main rudder and the main rudder to steer the ship. To provide for the housing of the hand-actuating gear the main rudder is built up hollow, as shown in the plan.
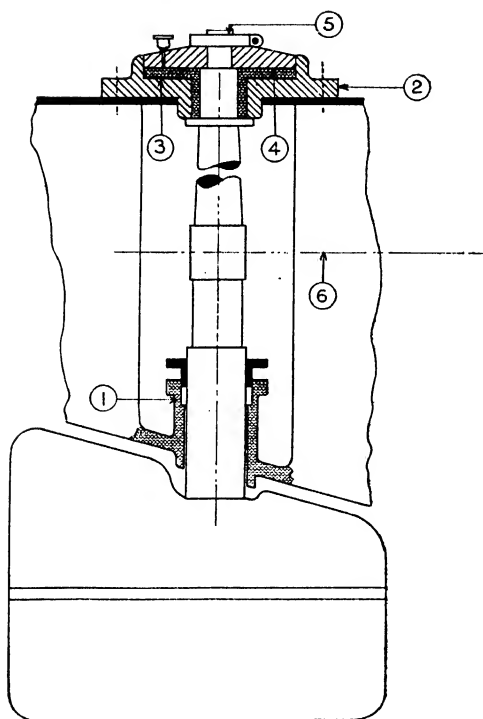
No. 579.—Balanced Type Rudder.

1, Gland.   4, Phosphor bronze liner.
2, Steel seating ring.   5, Locking ring in halves.
3, Phosphor bronze bearing.   6, Centre line of steering gear engine.

COOLING WATER AND LUBRICATING OIL CIRCULATION

As the safe working of marine oil engines depends to a large extent on the uninterrupted flow of the cooling water and lubricating oil, a short description of the " Monitor " patent safety devices will be of interest. These have been fitted in a large number of motor ships, including some of the largest liners.
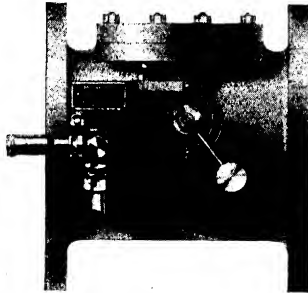
No. 580.—" Monitor " Flow Indicator with Whistle Alarm.

This fitting forms part of the pipe line, and may have flanged ends (as shown) or screwed ends, according to size. The flow through the pipe keeps the internal flap or disc valve open, an amount depending on the velocity of the flow, this being denoted externally by the position taken up by the balance lever, which forms the pointer over the flow indicator. The illustration shows the flow stopped, the tappet on end of spindle pressing up the ball valve lever in connection with the whistle alarm. Compressed air from a low-pressure source in the engine room forms the medium for blowing the whistle. The fitting is adaptable for either vertical or horizontal pipe lines, and the alarm can be set to operate at reduced flows as desired. On resumption of flow the gear automatically resets itself.
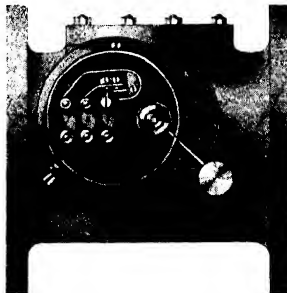
No. 581.—" Monitor " Flow Indicator with Electric Alarm.

The internal construction of this fitting is identical to the previous type, but the external gear consists of hinged members carrying silver contacts for " make " and " break " circuit respectively. No batteries are required, as a shunt from the lighting circuit is con-

nected to the feeder (2). Terminal (3) is for the pilot lamp circuit and terminal (1) for the alarm bell or horn. When the flow ceases, the lamp goes out and alarm sounds. The live parts are protected by plate glass front. The insulated contactor can be set to operate at any point on the flow indicator. The spindle gland allows freedom of movement without leakage, this being one of the novel features.
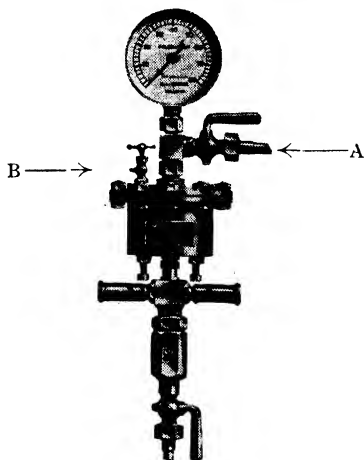
No. 582.—" Monitor " Pressure Alarm (Whistle Type).
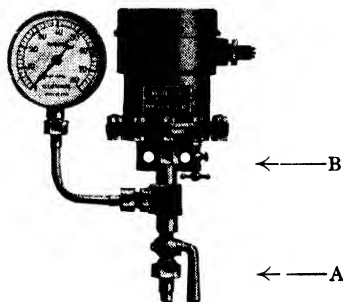
No. 583.—" Monitor " Pressure Alarm (Electric Type).

Under certain conditions fall of pressure denotes cessation of flow. This condition obtains in the case of forced lubrication to bearings where the flow is dependent on the pressure of oil. The " Monitor " pressure alarm is of the diaphragm type. The ball valve in connection with the whistles is kept closed as long as the pressure of oil on one side of the diaphragm is greater than the opposing spring at the other side. Fall of pressure allows the spring to force back the diaphragm, thereby allowing the compressed air to open the whistle valve and sound the alarm. This fitting may be placed in any convenient position in the engine room, being simply connected to the pipe lines by small copper tube. The alarm is tested by closing cock A and easing back relief cock B, watching the pressure gauge as the pressure falls to the point of alarm. Adjustment screws are provided for varying the alarm pressure if required.

This fitting is also applicable to the cooling water pumps of the centrifugal type if the alarm pressure is set in excess of the static pressure showing on the gauge when the pump is at rest, but less than the pressure on the gauge when the pump is working. The whistle then blows if the pump loses its suction. The apparatus is also supplied fitted with electric alarm in lieu of the whistle gear as shown by No. 583. Terminals for pilot lamp and horn are provided.

MOTOR   BELT   IDLER   BEARING

SPINDLE

DOOR

FRAME

WATER DISCHARGE   OIL DISCHARGE   BOWL

THREE WING

BRAKE

DRAG

FEED TUBE
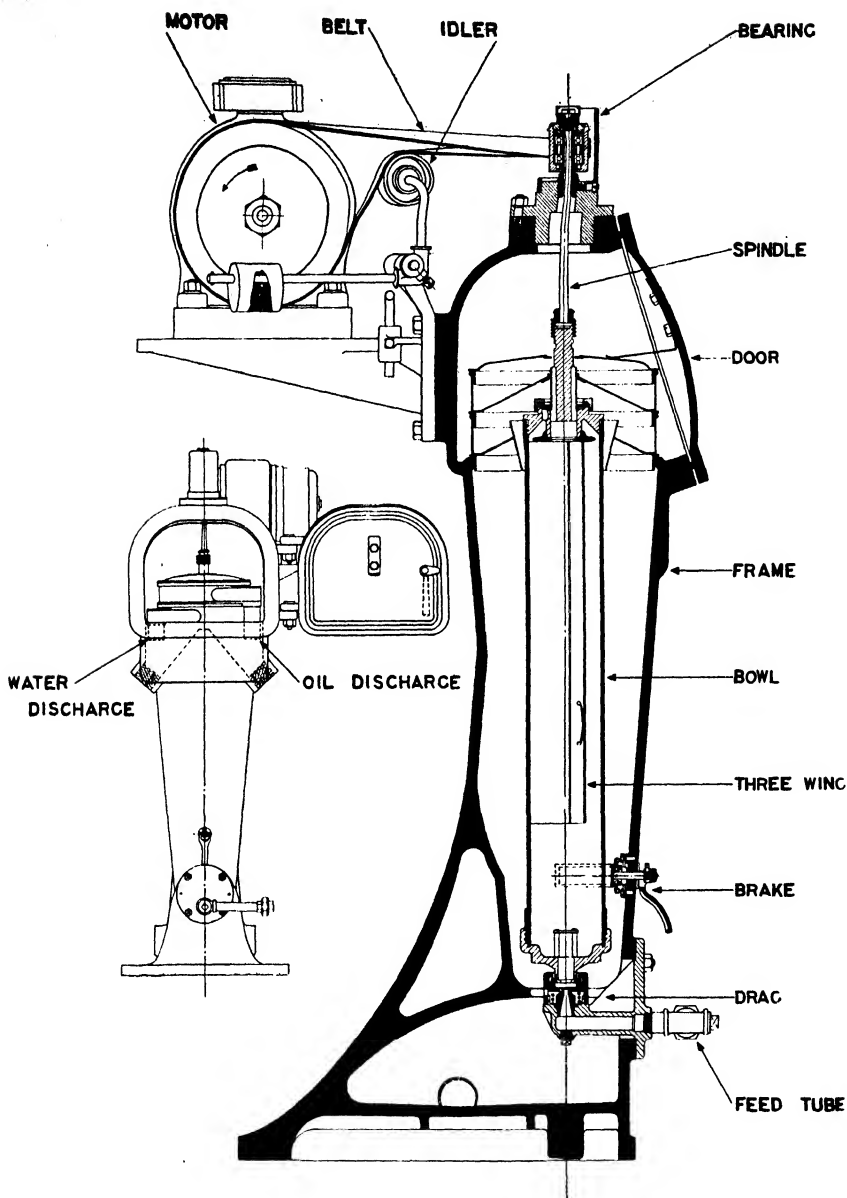
SHARPLES   SUPER   CENTRIFUGAL   OIL   PURIFIER.
TOTALLY   ENCLOSED   TYPE.

No. 584.—Sharples Oil Purifier.

Sharples Oil Purifier.

The bowl or rotor of this machine is of steel, tubular in design, viz., 4½ in. in diameter by 30 in. long, weighing from 35 to 37 lbs.

The bowl is housed in a conical-shaped cast-iron casing and is driven by an electric motor mounted on a bracket at the back of this casing. The bowl revolves at from 15000 to 16000 r.p.m., generating a centrifugal or purifying force of approximately 15000 to 16000 times that of gravity.

The bowl is suspended from a ball bearing by means of a flexible steel spindle. The bowl bottom revolves in a guide bushing—simply designed to limit any lateral movement that may develop.

The interior of the bowl is fitted with a removable three-wing piece for the purpose of preventing slippage of the liquid in relation to bowl speed.

The liquid to be treated is fed through the feed tube at the bottom and passes through a jet into the bowl, the discharge orifices being at the top of the bowl, for oil and/or water and these orifices can be adjusted so as to provide for perfect separation of the two constituents.

A brake is fitted for bringing the bowl to rest after it has been in operation.

The liquid under the action of centrifugal force flows upwards through the bowl, and should the liquid, e.g., fuel oil, contain solid suspensions and water, the three components will be stratified, the solid being deposited in the form of a hard cake on the inside wall of the bowl, the water travelling upwards and flowing from the lower outlet, and the oil in a similar direction, flowing from the upper outlet, these two liquids having their discharge from separate ports provided in the head and flowing into collecting covers, discharging from the spouts in the main casing.

The Sharples purifier is so designed as to enable it to be completely enclosed when in operation, thus avoiding any possibility of fumes escaping from the plant when oils are being treated at elevated temperatures.

As witness to the purification that is effected by these purifiers, it may be stated that during recent tests on Diesel engine fuel oil on board a well-known motor vessel, the ash content was reduced from 0·102 per cent. to 0·007 per cent., and the water content from 2·6 per cent. to less than a " trace."

The salient features in connection with this machine are the high degree of purifying force exerted, its extreme simplicity of construction, and by reason of this simplicity the ease with which it can be handled and operated. For cleaning purposes a period of only ten to fifteen minutes is required, as the machine can be stopped, the bowl demounted, the solid matter removed, and the purifier recommissioned in this time.
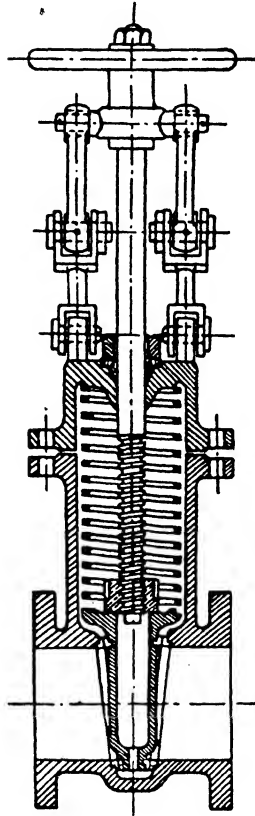
Sectional View.

No. 585.—Turnbull's Patent " Instanter " Quick-closing Sluice Valve.

This improved sluice valve can be opened and shut by the hand-wheel like any ordinary valve. In addition, however, it can be instantly closed from the deck position by pulling the wire rope.

The action of opening the valve compresses a powerful spring inside, which tends to thrust down the wedge and spindle. The latter is held up by the cross-head and side links, which form two toggle joints. The two toggle joints are coupled with the forked end of a connecting link, the other end of which is attached to the wire rope which is led to the deck station. A sharp pull on the wire rope breaks the toggle joint and permits the powerful spring to close the valve. To open the valve, the hand-wheel is revolved as if to close the valve, this movement raising the spindle in the spindle-nut and bringing the toggle joints and connecting link back to the original position. The connecting link should then be right home, and the valve is then ready for use again as an ordinary valve.
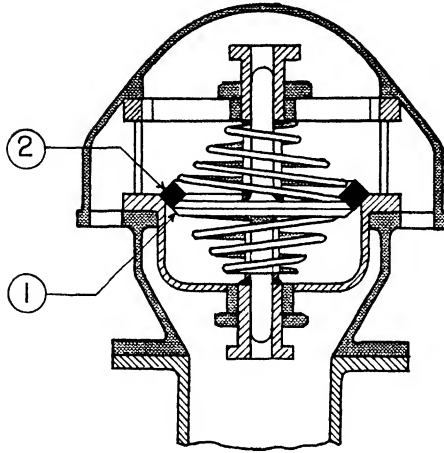
No. 586.

1, Lower solid valve.
2, Upper ring valve.

Blundell "Atmos" Tank Valve.

The valve is formed of a ring valve above and a solid valve below, the two being superimposed and with the faces bevelled off at angles of 45°. Light springs are fitted top and bottom as shown in the sketch, and the cage is surrounded by a gauze screen through which escaping oil gases require to pass when being relieved.

The action of the valve is as follows :—

1. When filling a tank, say, with oil, the air or vapour present is forced upwards by displacement and lifts up both the solid valve and the ring valve as one, thus relieving the pressure inside the tank.

2. When pumping out the contents of a tank, a partial vacuum is formed and the lower solid valve only is depressed and thus admits atmospheric air to the tank.

The valves are usually set to relieve any positive pressure in the tanks of over 4 oz. per sq. in.

The Pneumercator Tank-Gauge.

By Messrs Kelvin, Bottomley, & Baird.

The pneumercator tank-gauge indicates with precision and at a distance the level of any liquid and the weight or volume in any tank, standpipe, or reservoir.

It will also measure the draught of a ship, the depth of a river, the stage of the tide, the depth of water in a dock, etc.

The essential parts of the apparatus are :—

(*a*) The balance chamber.

(*b*) The mercury (or other) gauge which is calibrated in feet and inches of liquid depth and/or in the corresponding weight or volume.

(*c*) The air pump or other means for furnishing compressed air.

(*d*) The control valve directly attached to the gauge and also connected through piping (*e*) with the balance chamber and air pump.

(*e*) Small solid drawn air piping, which may be of any length, may pass through boiler rooms, refrigerators, etc., may be laid indoors or out, and in any direction.

The balance chamber is generally a more or less hemispherical vessel provided with a sharp-edged orifice near its base. It is located in the tank containing the fluid to be measured as near the bottom as possible.

The sharp-edged orifice referred to determines what is known as the datum level.

Briefly, the pneumercator gauge may be said to be actuated by the pressure due to the height of the liquid in the tank above this datum level, and in graduating the scale, due allowance is made for the height of the orifice above the bottom of the tank.

The head of liquid in the tank compresses the air trapped in the balance chamber, and the pressure is transmitted by the small connecting air pipe to the gauge, causing the mercury column to rise and fall as the pressure due to the head of the liquid in the tank increases or decreases.

The air pressure in the pipe line is obviously that due to the height of the liquid in the tank above the level of the liquid in the balance chamber.

The control valve or operating cock connects the balance chamber with the air pump or shuts off the air pump, and connects the balance chamber to the gauge—or disconnects all three elements as may be required for operating the instrument.

The balance chamber and gauge are shown in a simplified form in No. 587.

As explained, the air pressure in the balance chamber and small air pipe line varies with the head of liquid in the tank, and the mercury column is actuated directly by the air pressure in the pipe line.

Every time the level of the liquid in the balance chamber is brought back to the datum level by means of the air pump, the volume of the trapped air in the balance chamber will be the same;

Mercury.
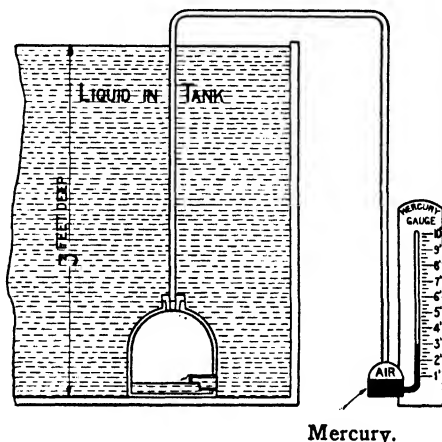
No. 587.—Trapped Air in Balance Chamber compressed by Head of Liquid in Tank.

thus, we may say that the volume of air trapped in the balance chamber must always be constant in order to obtain correct readings.

Suppose that the level of the liquid in the tank is low, and the level inside the balance chamber corresponds with the datum line. Now assume that the tank be filled. As the liquid head increases during the operation of filling, the air trapped in the balance chamber will be compressed into a smaller volume, and the level of the surface inside the balance chamber will rise above the datum line. Before a useful reading can be taken on the gauge, a few strokes of the hand air pump are applied, forcing air into the balance chamber, and this is continued until the level of the liquid in the balance chamber is depressed as far as the datum line; in other words, till the original volume of trapped air has been restored.

Mercury is usually employed in the indicating tube of the gauge which is calibrated for water or for oil of any given specific gravity as required.

TO GAUGE

TO TANK

AIR PUMP

BALANCE
CHAMBER

ORIFICE
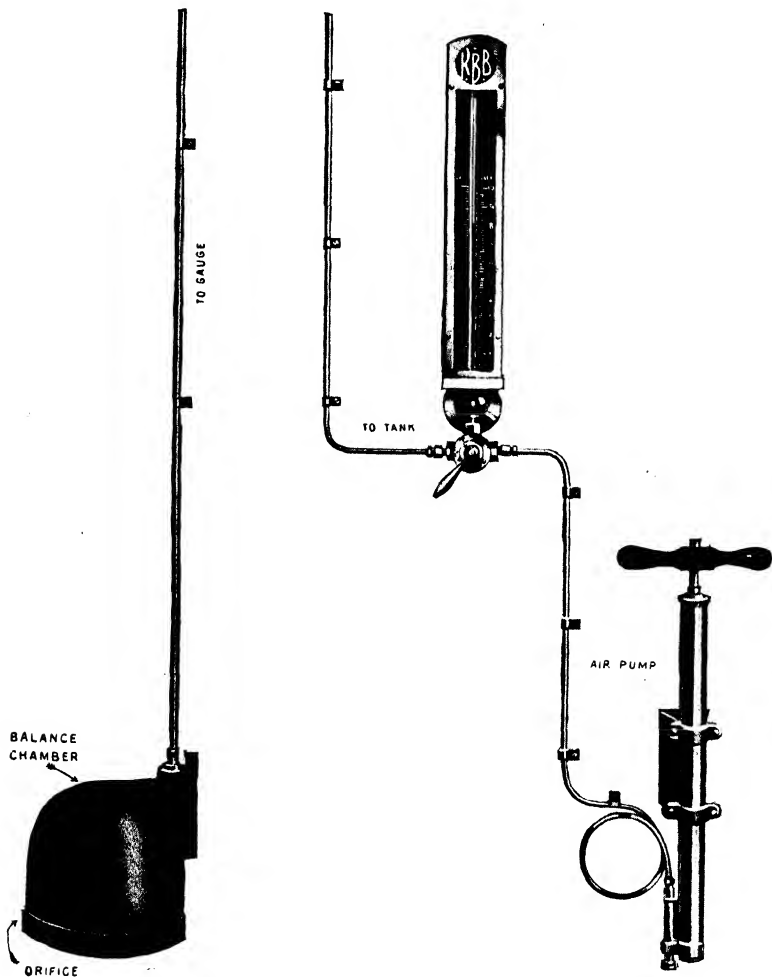
No. 588.—Pneumercator Equipment for One Tank.

Example.—The depth of fuel oil in the double bottom is, say, 2 ft. 6 in. ; find the corresponding gauge indication on the mercury column if the specific gravity of the oil is ·85.

Then,   Mercury height$=\dfrac{30\times ·85}{13·6}=1·87$ in.

The indication of 1·87 would then be calibrated on the mercury column to read off as 2·5 ft. of oil.

THE DRYSDALE PATENT "ROTARY-CENTREX" PUMP. (No. 590)

Owing to the difficulty of keeping pipe joints air-tight on board ship, self-priming pumps are necessary where the pumping conditions involve a suction lift. The Drysdale "Centrex" Patent self-priming pump, with its reciprocating air pump, is well known to all sea-going engineers and, no doubt, many will also be familiar with the latest addition to the existing range—the "Rotary-Centrex."

This construction embodies a moving element, which is entirely rotary, thus allowing a smaller number of working parts to be used and, therefore, reducing the weights and cost. No gears are fitted, the air pump being driven direct from the motor shaft, so that additional air capacity is available, due to the higher speeds of rotation.

The principle of operation of the "Rotary-Centrex" pump is exactly the same as the "Centrex," *i.e.*, the air is separated from the water and is then handled by an air pump of large capacity, while a centrifugal pump deals with the water. The air, when it is separated from the water, rises to the top of a suction chamber, forming a part of the pump casing, whence it is withdrawn by the air pump through a float-operated valve. When there is no air present in the water, the suction chamber becomes full of water and the float rising, shuts the valve between the suction chamber and the air pump.

The air pump operates on the water-ring principle, consisting of a rotor revolving in a casing of special form, which has been filled with fresh water. As the rotor revolves, since the casing is of varying diameter, the liquid is made to flow from and return to the centre of the rotor. This motion is taken advantage of to draw any air through one set of ports and discharge it, after compression due to the varying diameter of the casing, through another set.

The exhauster casing contains a water reservoir, which is filled on starting up for the first time with fresh water. This liquid forms the sealing medium for the air-pump rotor. The casing is surrounded by a jacket circulated by the water pump, but the capacity of the reservoir is sufficient to run the pump for an extended period

NO	NAME OF PART
1	PUMP CASING COVER.
2	IMPELLER CAP NUT.
3	DRAIN PLUG.
4	IMPELLER BEARING RING.
5	IMPELLER.
6	IMPELLER BEARING RING.
7	COMBINED NECK BUSH & LANT. RING
8	WATER SERVICE CONNECTION
9	PUMP GLAND.
10	PUMP SPINDLE SLEEVE.
11	PUMP SPINDLE
12	COUPLING BOLT
13	COUPLING NUT
14	MOTOR HALF COUPLING
15	MOTOR
16	AIR PUMP COUPLING
17	COUPLING NUT
18	PACKING PLATE.
19	CENTRAL VALVE PLUG
20	CENTRAL VALVE HANDLE
21	CENTRAL VALVE BODY
22	ROTOR
23	AIR PUMP VALVE PLATE
24	AIR PUMP RETAINING BUSH
25	AIR PUMP SPINDLE
26	AIR PUMP COVER
27	AIR PUMP SPINDLE CAP NUT
28	SUCTION & DISCHARGE MANIFOLD
29	CHECK VALVE
30	FILLING PLUG
31	INSPECTION WINDOW
32	AIR PUMP CASING
33	DISTANCE PIECE CAP
34	NEEDLE VALVE SEAT
35	BRIDGE PIECE NUT.
36	NEEDLE VALVE SPRING
37	BRIDGE PIECE
38	NEEDLE VALVE
39	FOIL PENDANT
40	DISTANCE PIECE
41	BALL FLOAT
42	BALL FLOAT BASKET
43	
44	PUMP CASING
45	REGULATING NEEDLE VALVE

No. 590.—The Drysdale Patent "Rotary-Centrex" Pump.

if, for any unforeseen reason, there is difficulty in obtaining from the centrifugal pump the cooling water supply for the jacket. The sealing water, in circulating between the rotor and the reservoir when the pump is running, is cooled by contact with the walls of the water-jacketed space.

This cooling water is taken from the pump discharge branch and returned to the suction side of the casing, thus forming an entirely closed circuit. In this way, pure clean water is utilised in the air-exhausting pump, which has no direct contact therefore with the sea or bilge water handled by the centrifugal pump, thereby securing maximum life of the working parts of the air exhauster.

A control valve of patented design is mounted on the front of the pump, whereby the air pump may be placed in or out of operation, as may be desired.

SCREW DISPLACEMENT PUMPS

Messrs STOTHERT & PITT LTD., BATH

In order to meet the requirements of the lubricating-oil service in the engine-room of a modern motor ship, it is generally agreed that the pumping unit should be of the vertical pattern occupying little space, and that it should be capable of running continuously, maintaining volume output and pressure under varying conditions of suction lift and delivery head. It is quite usual for the pump to be set up with its suction branch between 8 and 10 ft. vertically above the level of the oil in the ship's double-bottom tank. The circulation of the lubricating oil through bearings and in the cooling of pistons causes considerable aeration, and in certain cases the end of the suction line may be momentarily uncovered, due to the movement of a ship. It is often necessary that the lubricat-

No. 591.—Sectional Elevations of the Screw-Displacement Pump.

ing-oil pump be capable of working uninterruptedly, drawing from the double-bottom tank large proportions of air, and at certain times, perhaps, to exhaust air only until such time as the suction pipe is immersed in the body of the oil.

For this purpose Stothert & Pitt, who for some years past have built pumps for bearing-oil and piston-cooling services, have now developed a screw-displacement pump of a vertical design, as indicated in the accompanying illustrations.

Special tests have been made to prove the efficiency of this pump under the foregoing conditions. The tests included the running of the pump with lubricating oil under a static suction lift of 8 to 10 ft. against a discharge pressure of 50 lbs. per sq. in., and during pumping proportions up to about 90 per cent. of air to oil were admitted through a snifting valve in the suction line. Under this

condition the pump continued to run quietly, exhausting the mixture of air and oil.

A further test was made with the end of the suction pipe raised to the surface of the oil in the source tank, so that a heavy vortex was created round the pipe end and a large proportion of air drawn in. During this trial the pump continued to run smoothly, dealing with the mixture of air and oil and maintaining pressure on the discharge gauge. Special observation was made of the effect produced by intermittently opening and closing the main valve in the suction line, so as to imitate the condition which might be met on board ship, when in a heavy sea the oil might leave the suction pipe temporarily uncovered. It was noted that however rapidly the suction valve was manipulated, the pump continued to run smoothly without vibration or hammer rising from cavitation, and pressure was maintained at the discharge gauge until the flow ceased, due to the suction valve being completely closed.

An important feature of this design is that with a suction valve gradually closed until a vacuum reading of over 29 in. of mercury is registered, the pump passes through the usual critical stage associated with cavitation with practically no hammer effect.

No. 592.—Electrically Driven Vertical Screw-Displacement Pump for Lubricating Oil.
(Messrs Stothert & Pitt Ltd.)

The exclusive licence in Great Britain for the manufacture of this screw-displacement pump, which is built to the Houttuin system, is held by Stothert & Pitt, who have supplied the pump for salt and fresh water circulating, bilge and sanitary, lubricating oil, fuel oil, and for cargo services.

VALVES SHOWN THUS ⊠
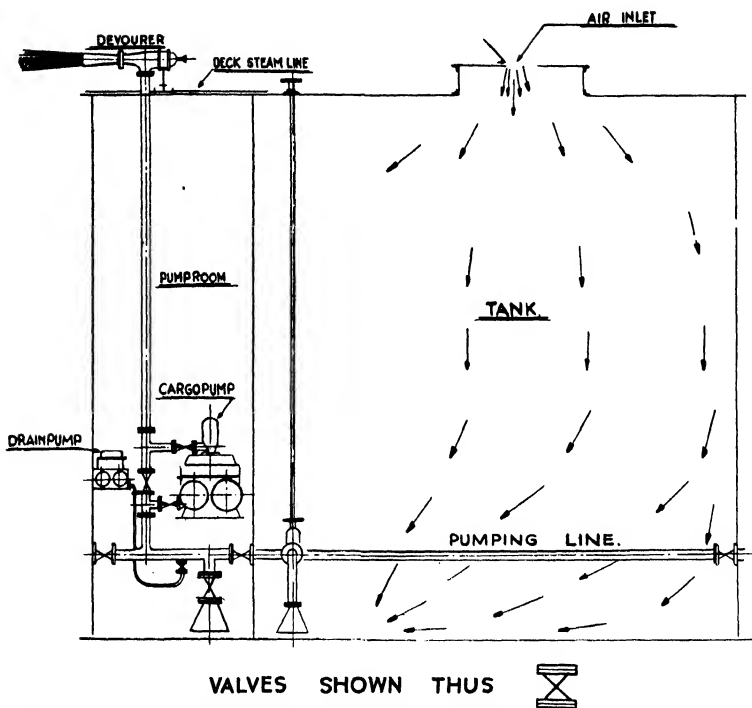
No. 593.—Patent Gas Devourer, for the Gas-freeing
of Oil Tanks.

(Constructed by the Rotterdam Dry Dock Co.)

After the pump-room or tank has been efficiently drained, the deck steam
connection to the ejector is opened up and the gases are exhausted from the
compartment to which connection is made, other tank connections being mean-
while shut off. When a tank is being exhausted, the inspection door on the
hatch cover should be removed to permit of the admission of fresh air to the
tank to take the place of the foul gases being removed.

The steam ejector is coupled up on deck to the main pump line, as shown
in sketch, and the gases are exhausted to the atmosphere.

For a tank inlet suction pipe connection of, say, 6 in. diameter, the required
steam pipe connection is $1\frac{1}{2}$ in. diameter.

It should be noted that all the tank valves may be operated from the deck
by means of extension rods and hand wheels as shown.

No. 594.
Gear Type Oil
Pump.

**Cover Removed,
showing Wheels.**

Note.—With suction branch
on left, the upper gear wheel
revolves right hand, and the
lower gear wheel left.

Gear Type Oil Pump.

The pump consists of two small toothed wheels gearing, with
one another, and fitting exactly into an iron casing. When running,
the oil is urged round between the wheels and case, the oil filling
the spaces between adjacent teeth. As there are no valves or
springs, etc., the pump is practically immune from breakdown.

The oil, after leaving the bearings, returns to a large reservoir
and thence to an oil settling tank wherein any water carried by the
oil can be separated out. In the suction pipe, between the reservoir,
and pump, a strainer is placed to arrest any foreign matter; this
strainer can be cleaned or renewed without stopping the supply of
oil to the pump.

The oil is also cooled on its way to the bearings by passing
through an oil cooler containing tubes through which cold water is
circulated, and amongst which the stream of oil is distributed with
consequent loss of heat.
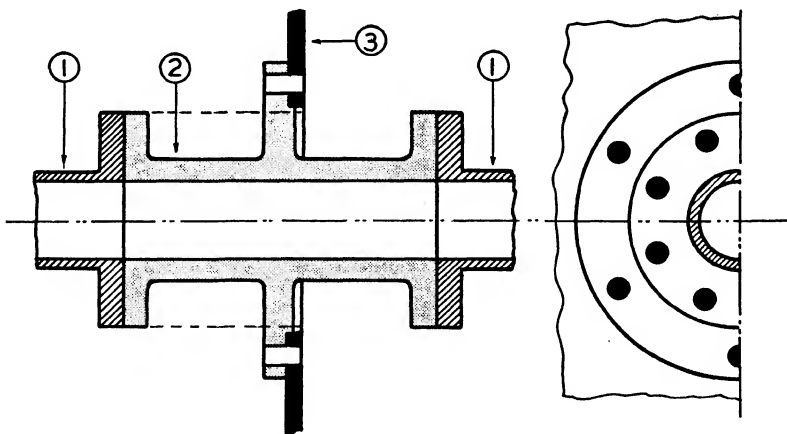
No. 595.—Water-tight Bulkhead Fitting.

1, Ballast, bilge, or other pipe.
2, Gland extension piece.
3, Bulkhead.

Note.—When main steam pipes pass through bulkheads, expansion-type
glands are usually fitted.
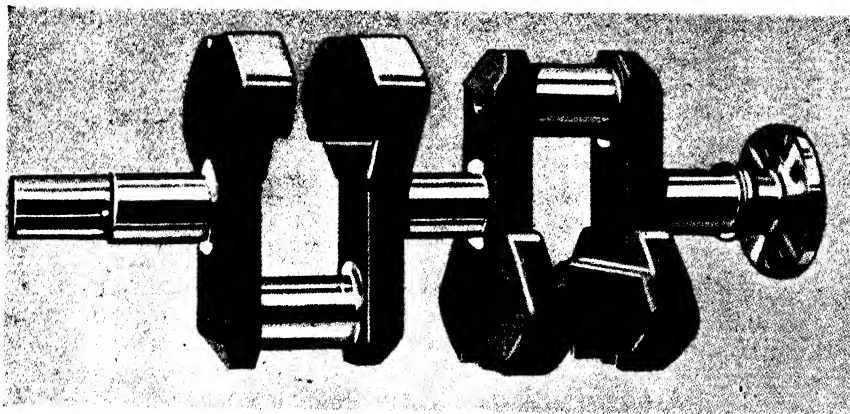
No. 596.—Balanced Crankshaft of 2-Cylinder " Brush "
Type Oil Engine.

The balance weights are checked on to the crank webs, and are secured
in position by means of high tensile strength steel studs, as shown in the
illustration. Balance weights are fitted on engines with few cylinders, say
2 cylinders, 3 cylinders, and 4 or 5 cylinders, also in engines which are
without flywheels, such as double-acting main engines.

The balance weights are intended to counterbalance the effect of the
unbalanced reciprocating masses of the engine and thus reduce torsional
vibrations on the main shafting.
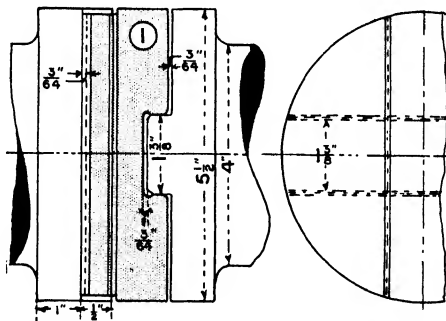
No. 597.—Valve Lever Shaft Expansion Allowance.

(Sulzer Engine.)

The lever shaft for valve actuation is placed in bearings on the cylinder
heads, and to allow for the effects of heat expansion a coupling is provided, as
shown above. This consists of a pad $\textcircled{1}$ which connects the two lengths of
shafting. The shaft ends are arranged with projections or feathers placed at
right angles to each other, and these register into corresponding recesses on
the shaft end flanges, an expansion allowance of about $\frac{3}{64}$ in. being allowed for
at two positions, as indicated in the sketch.

—235 mm Dia—→
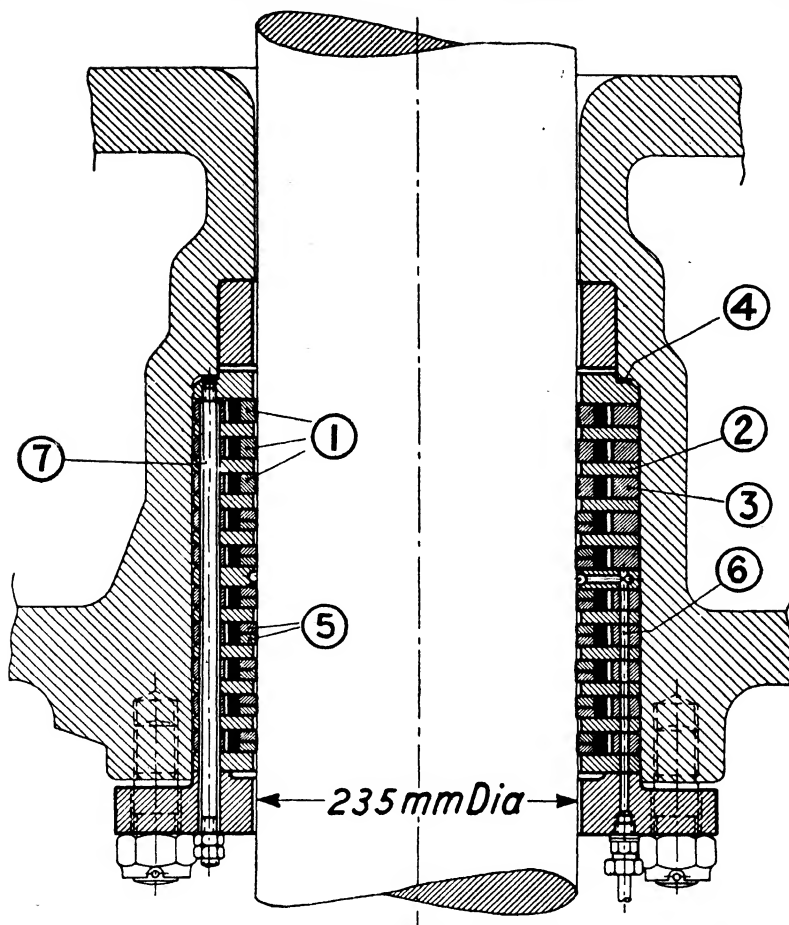
No. 598.—D.A. Diesel Engine Piston Rod Packing.

Reproduced, by permission, from the Paper read by Dr Ing. F. Sass at the Institution of Engineers and Shipbuilders in Scotland, on 9th April 1929.

1, Fire rings.

2, 3, Chamber rings.

4, Copper ring for gas tightness.

5, Double piston rod packing rings.

6, Lubrication hole.

7, Locating bolts (3).

The locating bolts prevent the various rings from turning in the gland space. Piston rod rings are of inspring type and the chamber rings of outspring type, spacer rings (shown in black) are also fitted behind the packing rings to prevent the latter from being locked when tightening up the gland.
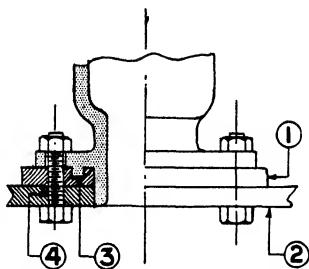
No. 599.—Method of Jointing Valves to Shell of Starting
Air Tanks.

1, Doubling plate riveted to shell.
2, Shell of tank.
3, Spigot with copper ring joint.
4, Studs screwed through doubler and shell thickness
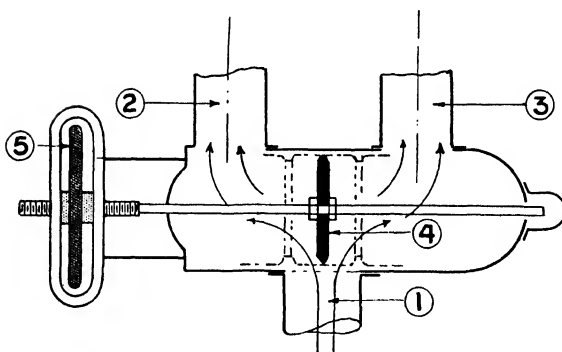
No. 600.—Controlling Valve for Exhaust Gas Flow.

1, Exhaust from engine cylinders.
2, Discharge of gases to waste heat boiler.
3, Discharge of gases to atmosphere.
4, Controlling valve.
5, Wheel and nut for screwed spindle.

When the valve 4 is moved to right the exhaust gases pass to the waste heat
boiler; if moved to left the gases will pass to the silencer and atmosphere.
At any intermediate position the gases will flow to both the waste heat boiler
and the atmosphere as required.

Ventilation.

Effective ventilation of machinery spaces may be obtained by the use of exhausting fans which withdraw the heated and impure air and allow of the admission of fresh pure air to take its place, or by the use of air fans which deliver air at low pressure and thus drive out the warmer impure air. Natural ventilation may be obtained by the effects of heat convection currents which cause the foul, heated air to expand and pass upwards, the colder and heavier fresh air from the ventilators displacing the former.

In Diesel-engined vessels the engine-room atmosphere may become impure and therefore injurious through the following causes :—

1. By the slow and gradual evaporation of oil from leaks in pipe joints, tanks, etc., or by leakage of gas from D.A. piston rod glands.

2. By the escape of exhaust gases from, say, exhaust boxes, leaky piston rings (2-cycle), piston rod glands in D.A. engines, and similar connections.

As exhaust gases are chiefly composed of CO_2, CO, nitrogen, etc., the air gradually becomes vitiated owing to want of oxygen, without which latter element life cannot exist, and the air becomes in consequence poisonous to breathe for long sustained periods. Enclosed crank cases usually contain quantities of oil vapour, which is injurious to health, and in addition, may be explosive when brought in contact with a flame or a mechanical spark (chain drives).

In one system which has been adopted in practice, a pump is employed to extract the vapour from the various crank cases, and passes the same through the tubes of a small condenser. The vapour is condensed and a small quantity of oil thus recovered for use again. The temperatures at various positions of the engine-room vary greatly in different cases, the highest usually being in the vicinity of the cylinder heads and exhaust boxes. Compressor cylinders usually also develop high temperatures before delivery to the coolers.

The coolest part of the engine-room is at the level of the bottom platform, and the highest temperature at the position of the top platform.

Drawing the Propeller Shaft.—The usual method of drawing in the tail end shaft for examination or repair is as follows :—

With steamer in dry dock, have all necessary working gear at hand, such as : chain and wire rope tackle, strong wooden blocks, screw or hydraulic jacks, light ram for coupling bolts, etc.

1. Fit up suitable staging round propeller.

2. Disconnect tunnel shafting and remove to one side two lengths of same.

3. Place tackle in position for drawing in tail end shaft (usually consisting of rope and chain blocks).

D.E.—57

4. Remove gland and packing and shore off coupling of tail shaft solidly from stern tube end by means of the wooden blocks mentioned previously.

5. Remove nut at back of boss, by means of blows from a hammer on the large spanner, having previously secured the propeller from turning.

6. Drive in steel wedges hard up between boss and stern post, or by means of a ram (hydraulic) force boss off the taper.

7. Connect up propeller to tackle, and draw tail shaft gradually into tunnel, supporting it by blocks as it emerges.

NOTE.—Very often the boss is found difficult to start, and when this is found to be the case one of the following methods may be tried :—

1. Build a fire below the boss, and when heated up apply blows from a large hammer on the end of the shaft, or the pressure of a ram or by steel wedges.

2. Bore a number of holes into the metal of the boss, then try the heating up, etc., as before. The holes are to allow of easier expansion of the boss when heating up.

When the vessel is in dry dock, examination and testing should be made as to wear down of the propeller shaft, also for signs of corrosion on shaft at end of liner and tightness of rubber ring. The propeller blade flange nuts should be tested for tightness and the blades examined for corrosion. The boss nut should also be tested for tightness and the stern gland packing withdrawn for examination.

Strength of Diesel Engine Cylinder Liners.

The strength of cylindrical vessels subject to internal pressure, such as cylinder liners, varies inversely as the diameter and directly as the thickness.

Allowing, then, a working tensile stress on liners of, say, 3,300 lbs. per sq. in., the thickness may be calculated as follows for, say, a 30 in. diameter liner, and allowing a maximum pressure of, say, 550 lbs. per sq. in.

Then, $30 \text{ in.} \times 550 = 3300 \times T \times 2.$

So that, $T = \dfrac{30 \times 550}{3300 \times 2} = 2.5 \text{ in.}$

The thickness as calculated refers to the upper end of the liner where maximum stress conditions exist, the liner being cast thinner at the lower end.

Liners are constructed of special cast iron (sometimes called "semi-steel") possessing a hard machining surface and properties of resistance to distortion due to severe heat stresses.

The tensile strength of the material ranges from 14 to 16 tons per sq. in.
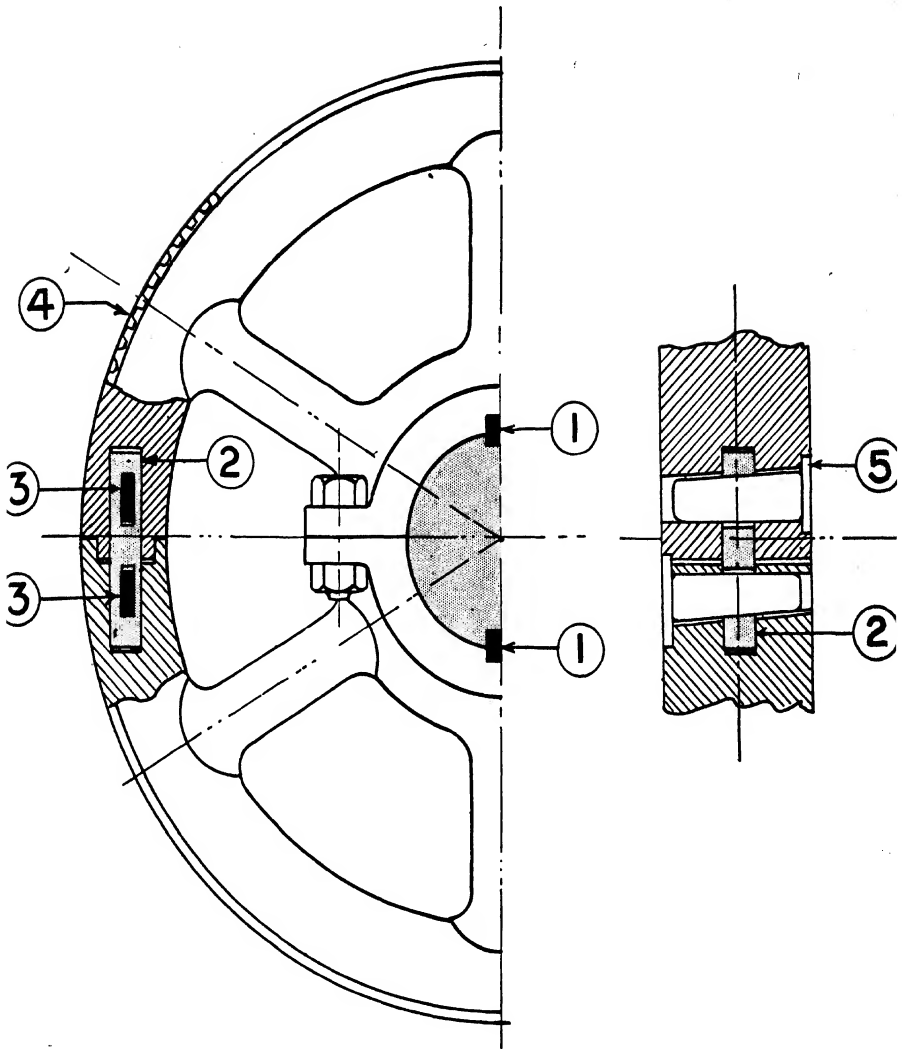
No. 601.—Diesel Engine Flywheel.

(For heavy power engine.)

1, Keys for securing wheel to shaft coupling flanges.
2, Heavy steel fitted pins.
3, Cottars for tightening up pin contact and rim.
4, Section of rim cut for turning gear teeth.
5, End locking plates of cottars.

NOTE.—In some cases the flywheel is formed solid, and is keyed and secured to the crankshaft coupling flanges.
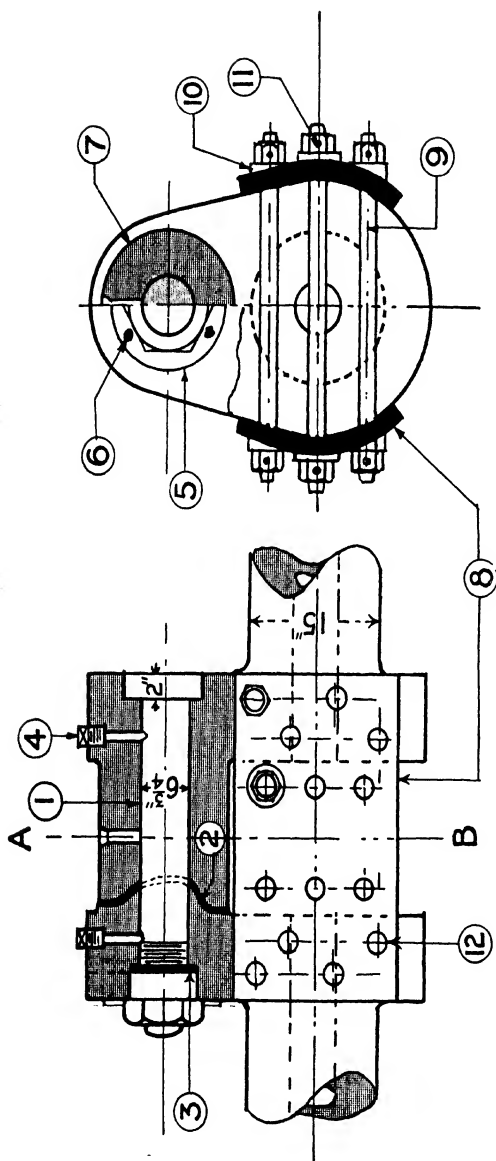
No. 602.—Broken Crankpin Temporary Repair.
(Part Section.)

1, Steel bolt, 6¾ in. diameter, a force fit through the broken crankpin.

2, Fracture.

3, Steel washer, ¼ in. thick.

4, Stopper pins.

5, Locking plate.

6, Set pins, ½ in. diameter.

7, Crankpin, 15 in. diameter. The crack in the crankpin 2 was guttered out to a depth of about 1½ in. and was then welded up to form the fillet. The straps were welded at the edges to the crank-webs, and one end of the 3 in. diameter through bolts were welded solid with the washers.

8, Straps machined and made up to a thickness of 2⅞ in. by means of three plates each ¾ in. thick and one plate ⅝ in. thick.

9, Six bolts, each 3 in. diameter.

10, Bevelled washers.

11, Pinching pins, each ¼ in. diameter.

12, Eight set pins per side, each 2 in. diameter and screwed 3¾ in. into the web thickness

Data.

T.S. (B. & W.) Diesel engined vessel with six cylinders per shaft.

Diameter of cylinders = 630 mm.
Stroke = 960 mm.
Revolutions = 125 (full power).
I.H.P. (combined) = 3000.
Diameter of shaft and crankpin, each 15 in.
Solid forged crankshaft lengths.

Description of Breakdown.

Symptoms.—The crankcase of No. 6 starboard engine was noticed to show an increase of temperature together with the generation of vapour, also the lubricating oil consumption was observed to rapidly increase with fall of pressure.

When the engines were stopped the fracture became clearly evident. When running, the nature of the fracture (see sketch) allowed the bottom end bearing to hold the fractured sections together, but when stopping and reversal of engines took place the broken sections of the crankpin completely separated and showed a clear air gap.

Method of Running.

The starboard engine was disconnected and the propeller shaft allowed to revolve on the trailing collar aft, the ship being run with the port set only, and at about one-third the previous speed, the turning gear being put in position to prevent movement of the starboard engine.

Repair.

On arrival at a foreign port the temporary repair shown in the sketch was carried out by the local engineering works, and proved to be efficient in every way. The crankshaft and pin of No. 6 cylinder was required to be able to transmit the power of the other five cylinders through to the tunnel and propeller shafting, with No. 6 cylinder cut out.

The sketch, with dimensions, illustrates how this result was successfully attained, the vessel arriving at the home port at reduced speed and without further trouble.

NOTE.—Had the crankshaft been of built construction in place of being solid forged, the breakdown might not have taken place, owing to the greater flexibility obtained by the built construction.

Example of Lubricating Oil Consumption.

B.H.P. = 1650.

Fuel = 7·6 tons per 24 hours (all purposes).

Lubricating oil = 1·5 for cylinders + ·5 for compressor + 8 for mains
    = 10 gals.

Specific gravity of oil = ·9.

Then

$$\frac{10 \times 10 \times \cdot 92 \times 100}{7 \cdot 6 \times 2240} = \cdot 54 \text{ per cent.}$$ lubricating oil consumption referred to fuel

consumption. This result represents good practice.

Example of Wear-down Records.

(Four-cycle S.A. engine.)

For one year $\begin{cases} \text{Top ends} & = \frac{6}{1000}, \text{ or } \cdot 006 \text{ in.} \\ \text{Bottom ends} & = \frac{8}{1000}, \text{ or } \cdot 008 \text{ in.} \\ \text{Main bearings} & = \frac{4}{1000}, \text{ or } \cdot 004 \text{ in.} \end{cases}$

The 3-stage compressor top-end wear was equal to $\frac{1}{1000}$ or ·001 in. after five years' service, and the bottom end of same $\frac{5}{1000}$ or ·005 in. after five years' service.

Charles's Law of Gases.

Charles's Law states that the absolute pressure of a gas varies directly with its absolute temperature if the volume remains constant, or, conversely, the volume of a gas varies directly with its absolute temperature if the pressure remains constant.

Hence

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} = \text{Constant.}$$

Combining Boyle's Law and Charles's Law we obtain the following:—

$$\frac{P_1 \times V_1}{T_1} = \frac{P_2 \times V_2}{T_2}, \text{ or } P_1 \times V_1 \times T_2 = P_2 \times V_2 \times T_1.$$

Relation between Pressure, Temperature, Volume, and Weight of Air.

Rule.—$PV = 53 \cdot 2 \times W \times T°$.

P = Pressure per square *foot* absolute.

W = Weight per cubic foot in lbs.

T = Absolute temperature, Fahrenheit.

V = Volume in cubic feet.

NOTE.—The constant 53·2 is obtained by dividing the foot-lbs. due to atmospheric pressure per square foot area and volume by the absolute temperature of 32° F., or 460° + 32° = 492°, as 1 lb. of air at 32° F. possesses a volume of 12·36 cub. ft.

Then

$$\frac{144 \times 14 \cdot 7 \times 12 \cdot 36}{32 + 460°} = 53 \cdot 2 \text{ constant.}$$

Engineers' Duties.

$$\text{Watches}\begin{cases}\text{12 to } 4 & \text{3rd—6th—9th}\\ \text{4 to } 8 & \text{2nd—5th—10th}\\ \text{8 to 12} & \text{4th—7th—8th}\end{cases}\text{Engineers on watch.}$$

	Duties at Sea.	Duties in Port.
2nd - -	Take indicator diagrams, work out H.P. and fuel consumption, set engines to obtain best results.	General supervision of engineers and all work being done by them or the men.
3rd - -	Responsible for the steering gear and telemotor. Keep rough log up to date.	Cylinder heads, top and bottom ends and guides of port engine.
4th - -	In charge and responsible for 1 main generator and emergency generator, also starting and reversing gear for both engines.	Cylinder heads, top and bottom ends and guides of starboard engine.
5th - -	In charge and responsible for 1 main generator, 1 main compressor, and auxiliary compressor.	For gear mentioned.
6th - -	In charge and responsible for 1 main generator, 1 main compressor, all lubricators.	For gear mentioned.
7th - -	In charge of all emergency gear other than generator, i.e., emergency pumps, emergency steering gear, also separators and filters.	Clean all separators and filters, also fuel pumps, as directed by 2nd engineer.
8th - -	W.T. doors and all gear connected with same, also to see that all spare valves are ready for immediate use, also all mounting connected with H.P. air supply to mains and auxiliaries. Keep records of fuel and lubricating oil consumption.	Telegraph, receiving counters, and receiving and storage of fuel and lubricating oil for new voyage.
9th -	All fire-fighting appliances and spares for same, also refrigerator.	Refrigerator.
10th - -	To work to orders of 2nd engineer and assist where necessary.	To assist where necessary.

Chief Engineer's Duties.

In Port.—To interview captain and obtain all information *re* coming voyage, also possible duration of same. From this calculate the necessary fuel required, stores, etc., and order same. Get reports from 2nd engineer *re* repairs being executed aboard and ashore, and expedite same. Satisfy himself that all repairs have been executed to his entire satisfaction and in a workmanlike manner and suitable for coming voyage. Satisfy himself that sufficient stores for voyage are aboard and properly stored.

At Sea.—To make himself thoroughly acquainted with the daily runs, and consumption of all stores, log same and calculate remainder in order to be able if possible to finish voyage on same. Keep good log up to date, and advise owners and captain *re* general condition and quantity of consumable stores, particularly fuel and lubricating oil.

Second Engineer's Duties.

To allocate work to all hands and see same is executed, also consult with chief engineer regarding running of engines and setting of same.
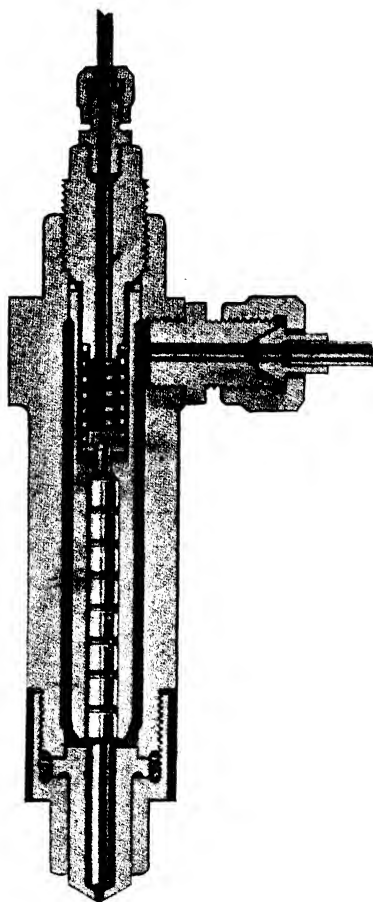
No. 603.—Section through Ruston Type Atomiser.

(Ruston & Hornsby Diesel Engine.)

Action.

The fuel under pressure from the fuel pump enters on the right, and passing down the clearance space lifts the valve by acting on the differential area of the spindle, the grooves shown serving as oil-packing spaces. The pressure load thus exerted functions to overcome the resistance of the spring compression above, and the valve lifts off its seat, the fuel being forced through the small diameter openings in the close-ended cap. Any leakage past the spindle passes up vertically through the hole shown in the screw locking-nut and gland at top. The cut-off or closing of the fuel supply is determined by the setting of the by-pass or spill valve according to common practice.

Action of Fuel Pump and Cylinder Fuel Valve in Solid or Airless Injection D.A. Engines.

The fuel is forced into the cylinder in liquid condition and at pressures ranging from 4000 to 6000 lbs. per sq. in. by means of the fuel pump, which is cam-operated with spring return. An angled by-pass or " spill " port is cut on the pump plunger near the position of the fuel delivery outlet, this port being actuated by the rotational position of the plunger. The function of the spill port is to break the fuel delivery pressure to the cylinder at the position required by running conditions. When the spill port is uncovered the fuel pressure to the cylinder is suddenly checked and the surplus fuel is by-passed back to the suction side of the system. The fuel-pump cam times the position of the cylinder fuel injection valve opening, and the spill port times the closing of the fuel injection period. The position of the fuel valve opening will thus remain constant, but the closing angle will vary with the spill port action. The cylinder fuel valve is of the automatic spring-load compression type, and the fuel, on entering under pressure, lifts the needle valve against the spring compression by acting on a differential shoulder formed near the lower end of the valve spindle. A close-ended cap, or atomiser nozzle, is screwed to the lower end of the valve casing, and the fuel is injected into the cylinder through five or six small openings of about .020 in. in diameter, which are drilled through the cap thickness.

NOTE.—The inlet oil pressure to the fuel pump suction is about 40 lbs. gauge, this being obtained by means of a separate motor-driven pump of low power. See also page 908.

New Sulzer Airless Injection System.

The fuel injection pumps differ from those fitted on most solid injection engines, in that the *end* of the injection period is kept constant, while the effective stroke of the pump is varied by alteration of the *beginning* of the period of injection (similar to motor-car engine practice). In this way the timing is retarded when running at light loads and low speeds, which in itself is a very desirable requirement. This new injection system has given very satisfactory results, as proved by numerous tests carried out. A further advantage of this fuel system is that the fuel pump cams can be made symmetrical for both ahead and astern running, a single cam serving both purposes. No reversing gear is therefore required for the fuel pumps, reversing being effected entirely by means of the starting air distributers.

A   B   C
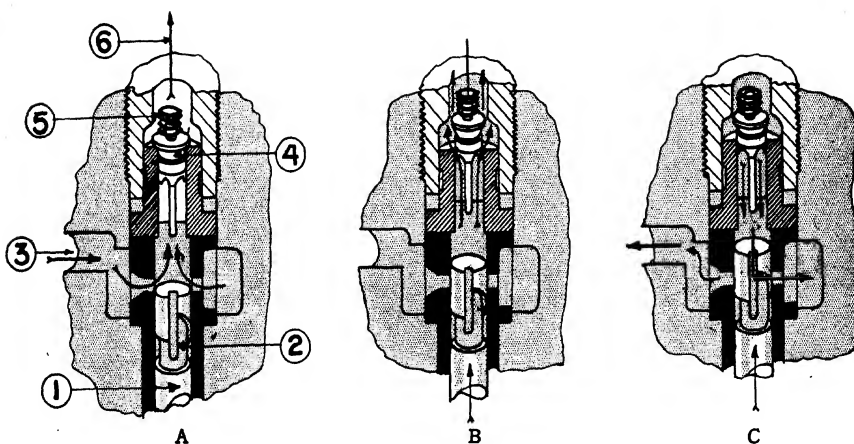
No. 604.—C.A.V.-Bosch Type Solid Injection Fuel Pump.

The plunger is cam driven on the delivery stroke with spring return action on the suction stroke.

1, Pump plunger.
2, Vertical channel and annular helix groove in plunger.
3, Pressure fuel oil inlet to pump.
4, Valve with circular groove and small piston.
5, Seating spring of valve.
6, Delivery to cylinder fuel valve which latter is of the spring load type.

NOTE.—By means of an external rack and pinion gear the pump plunger may be rotated by hand or governor, and thus alter the closing period of the fuel delivery by changing the position of the angled cut in the plunger in relation to the spill port in the casing.

A, Plunger at lowest point of travel and filling taking place.
B, Plunger moving up by cam action, and delivery to cylinder fuel valve taking place (shown by arrows).
C, Plunger still moving up but spill port on right now uncovered by angled cut, so that " spill " action begins, the fuel delivery being cut off and the surplus fuel returned to the low-pressure suction side of the system (shown by arrows).

Description.

Fuel is supplied from a tank preferably placed higher than the pump so that it flows easily through a suitable filter to the inlet connection under pressure and keeps the suction chamber in the pump casing full of clean fuel oil which can then be drawn readily into the pumping chambers of the various elements through two small lateral ports provided. To enable the pump to vary the quantity of fuel delivered per stroke, the plunger is provided with a vertical channel extending from its top edge to an annular groove, the upper edge of which is cut in the form of a helix. External means are provided whereby the plunger can be rotated in its barrel whilst working.

Operation.

The pump element is shown at the bottom of its suction stroke, two small ports being open and the pump barrel filled with fuel oil. On the next up, or delivery stroke, the plunger displaces fuel back through the two small ports until its top edge covers them, so that the remaining fuel is pressed out through the delivery valve via the pressure pipe to the nozzle in the engine cylinder valve. Since the plunger is of constant stroke this top edge will always cover the ports in the pump barrel in the same position of the cam rotation, so that injection at the nozzle will always commence at the same moment relative to the position of the engine crank. As long as the ports are kept covered by the plunger, the pump will continue to inject fuel through the nozzle, but before the plunger reaches the top of its stroke, the helical edge of its annular groove has uncovered the right-hand port, which enables the enclosed fuel to take the path of least resistance (via the vertical channel and annular groove), back through the port in the barrel to the common suction chamber. The position of the plunger stroke at which the helical edge will uncover the port is adjustable by rotating the plunger axially by means of a toothed quadrant which is clamped to a sleeve having slots engaging the lugs of the plunger at its lower end.

No. 605.—Delivery Valve of Fuel Pump with Light Spring.

Delivery Valve.

The upper part of the guide forms a small piston which is a highly ground plunger fit for the valve seating which is also internally ground. When the pump is on its delivery stroke, as the pressure of the fuel rises, the delivery valve is pushed up until the pressure fuel can escape through the longitudinal grooves over the valve face to the nozzle. Immediately the pump plunger releases the pressure in its barrel, the delivery valve (under influence of its spring and the great difference in pressure between the pump barrel and the delivery pipe) resumes its seat, causing the small piston parts of the guide to sweep down the valve seating with a plunger action, thus increasing the space in the delivery pipe (by an amount equal to the volume of the small piston part of the valve guide) before the valve actually seats itself. The effect of this increase of volume in the delivery pipe system is, of course, that of suddenly reducing the pressure of the fuel therein so that the nozzle valve in the nozzle can " snap " to its seat, thus instantaneously terminating the spray of fuel in the cylinder, entirely without " dribble."
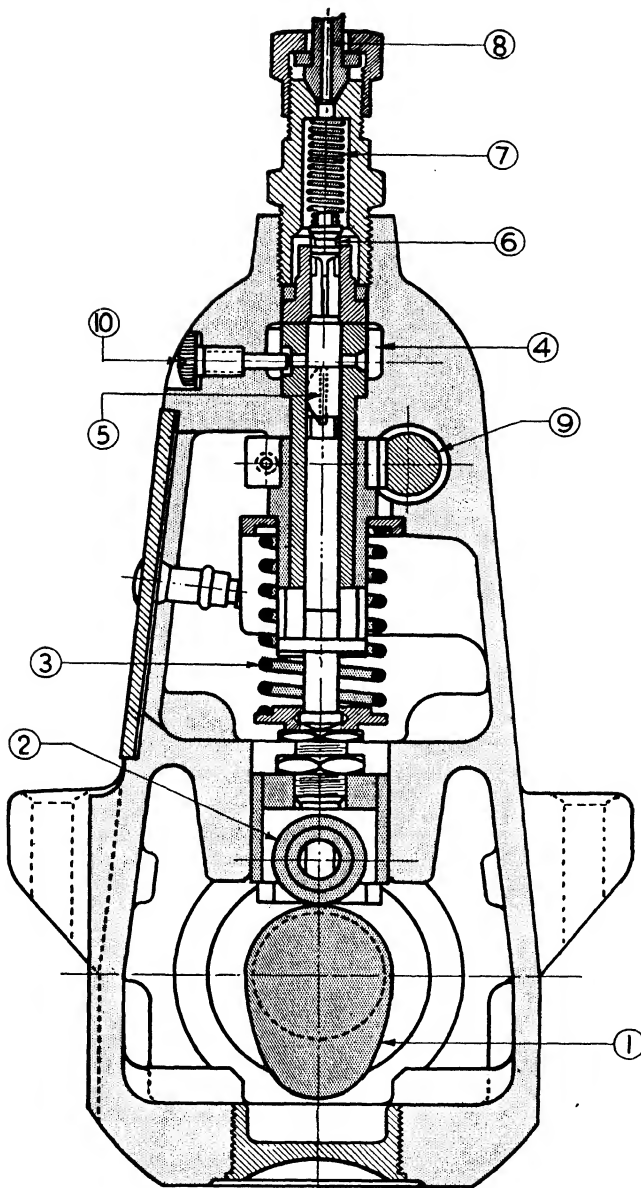
No. 606.—C.A.V.-Bosch Fuel Injection Pump.

1, Cam drive of pump.
2, Cam roller.
3, Returning spring for suction stroke.
4, Fuel·inlet recess.
5, Vertical slot in spindle for "spill" action.
6, Delivery valve.

7, Delivery valve spring.
8, Pressure delivery pipe to cylinder fuel valve.
9, Rack which operates pinion of pump casing.
10, Locking pin to limit rotary movement of pump case and pump plunger.

Note.—See p. 906 for action of spill port.
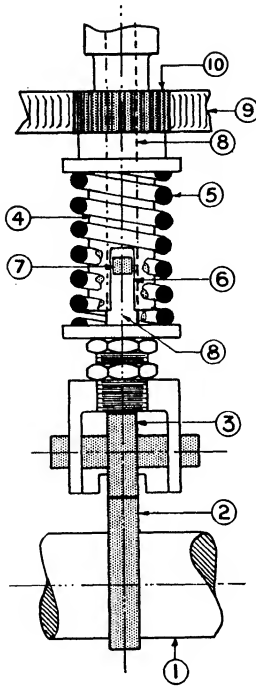
No. 607.—C.A.V.-Bosch Fuel Injection Pump.

View showing how pump plunger is rotated to alter fuel delivery timing.
(Plunger at top position.)

1, Shaft drive of cam.

2, Fuel-pump cam, solid on shaft.

3, Cam roller pivoted, as shown.

4, Fuel-pump case.

5, Spring return for plunger suction stroke.

6, Vertical slot in pump case and in which the small lug on pump plunger (7) registers, the effect produced being that when the case is rotated the pump plunger is also rotated.

7, Lug on plunger which registers with slot in case.

8, Fuel-pump plunger.

9, Rack which is operated externally by hand and governor gear to produce rotation of the case and with it the plunger, as described.

10, Pinion, solid on pump casing.

Ship Construction Details.
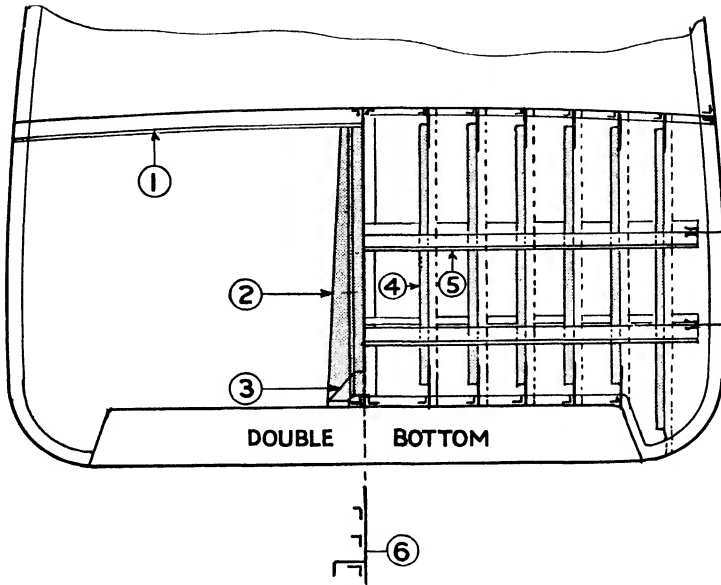
No. 608.—Deep Water Ballast Tank.

1, Deck beam.
2, Centre longitudinal bulkhead stiffeners.
3, Bracket at bottom of centre bulkhead.
4, Vertical stiffener angles.
5, Horizontal stiffener angles.
6, Plan view of centre longitudinal bulkhead.

NOTE.—" Round of beam " (camber) averages about ¼ in. per foot of beam.
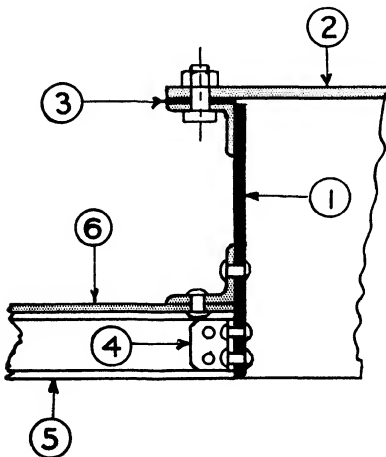
No. 609.—Water-tight Hatchway for Deep Tank, or for Oil Tank.

1, Hatch plating.
2, Hatch cover.
3, Joint of spun yarn and putty.   In some cases rubber or prepared rope is employed for jointing.
4, Clip connecting short beam to hatch plating.
5, " Short " or " strong " beam.
6, Deck plating.

NOTE.—In the case of oil tankers, the hatches are provided with pipe connections for gas extraction purposes by steam ejector action.
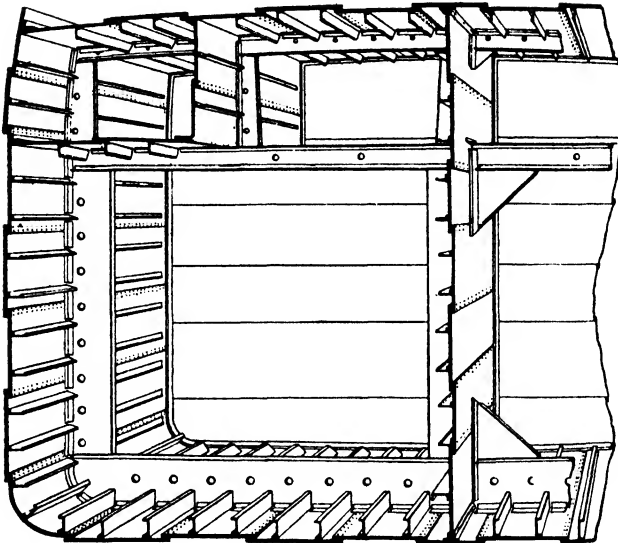
No. 610.—The Isherwood "Bracketless System" of Ship Framing for a Tanker.

"Longitudinals" are employed throughout, and the view shows the methods of support for the centre longitudinal bulkhead of the tank, etc. Caulking side on right and stiffening side on left.
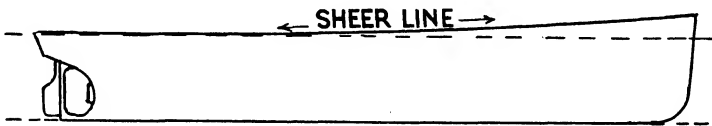
No. 611.—" Sheer " Line of a Vessel.
(Vessel on level keel in dry dock.)
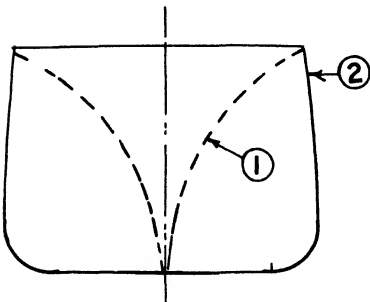
No. 612.—" Tumble Home " and " Flair."

1, " Flair " (at bow).
2, " Tumble home " (amidships).
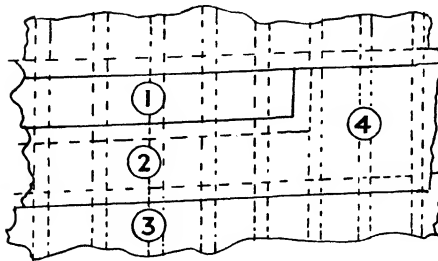
No. 613.—"Stealer" Plate.

1, Inner strake of plates.　　3, Inner strake of plates.
2, Outer strake of plates.　　4, "Stealer" of strake 2.

The "stealer" section permits of the omission of one of the strakes, which latter become narrow in width forward and aft.
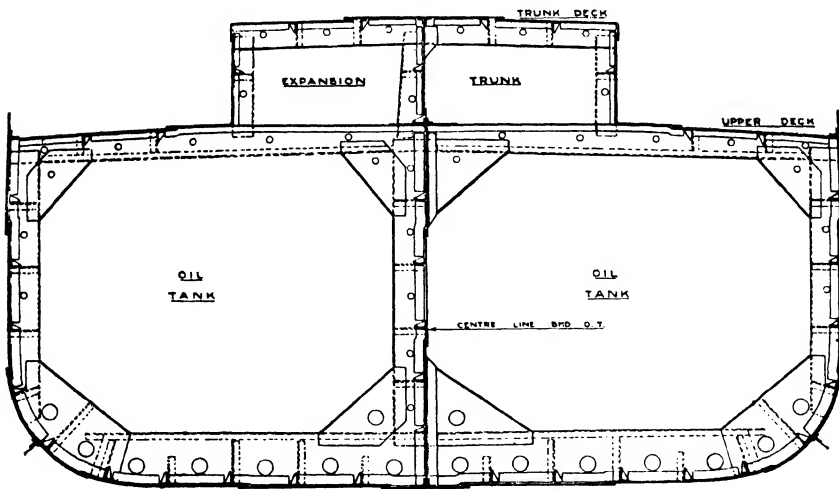
No. 614.—Midship Section through Tanker Vessel.*

This view shows clearly the stiffening of the centre longitudinal bulkhead, transverse frames, also the expansion trunks arranged above. Gas extraction pipes are usually fitted on this expansion trunk casing.

* Reproduced by courtesy of the Council of the Institute of Marine Engineers, London, from the paper entitled "The Care and Maintenance of a Modern Diesel-Engined Tanker Fleet," read by H. S. Humphreys, Esq. (Vice-Chairman of Council), 14th January 1936.
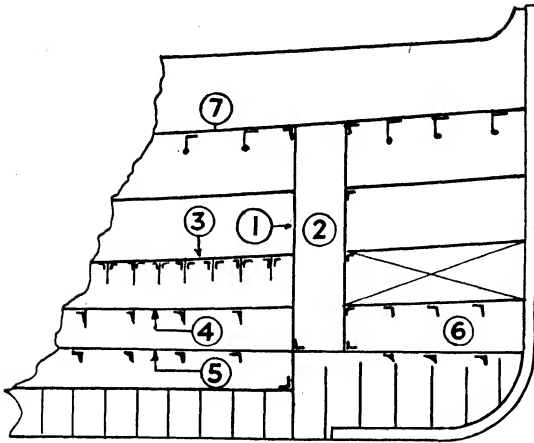
No. 615.—Collision Bulkhead and " Panting " Beams.

1, Collision bulkhead stiffened by means of vertical and horizontal double angle bars, etc.

2, Chain locker.

3, 4, 5, Panting beams and stringers, with angle bar, double angle bar, or bulb iron stiffeners.

6, Fore peak tank.   7, Upper deck.

No. 616.—Panting Stringers, etc. (to Stiffen the Hull against Collapse).
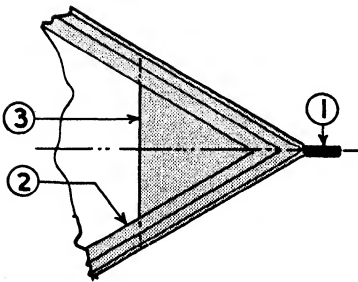
1, Stem of ship.

2, " Panting " stringer.

3, " Breast hook."

NOTE.—The breast hook triangular plate, or beam, is fitted to prevent collapse when the bow of the vessel plunges into heavy seas.
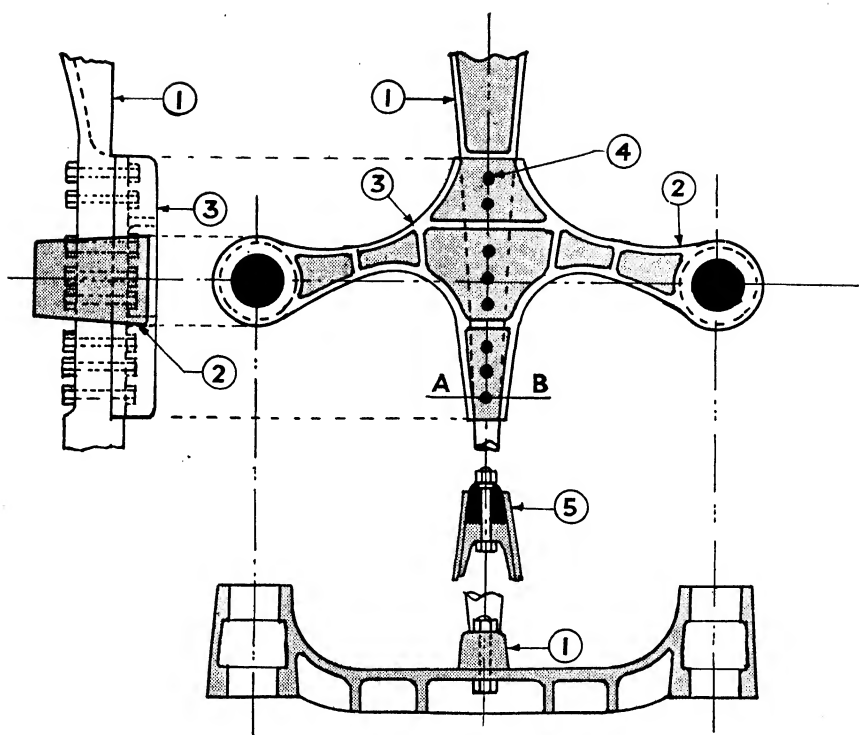
No. 617.—Cast-steel Stern Brackets (view from forward looking aft) for Twin Screw Vessels.

1, Forward stern frame or post of ship.

2, Spectacle eye for stern tubes.

3, Bracket which is cast in channel or trough section to allow of riveting to ship plating.

4, Fitted and turned bolts (3½ in. dia.) which secure bracket to stern frame of ship.

5, Section plan at position A, B.

NOTE.—The maximum diameter of rivet allowed is 1¾ in., and the rivets require to be turned and fitted. When placed in position cold, the closing ends are heated by a blow-lamp previous to setting up by hand hammering.
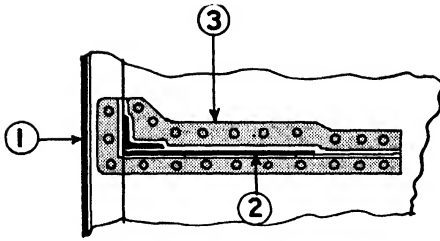
1, Shell.
2, Hold beam stringer.
3, Water-tight collar angle.
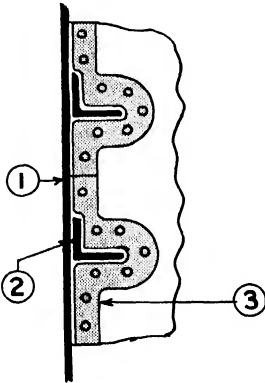
1, Shell plating.
2, Frame.
3, Water-tight collar.

No. 618.—Water-tight Collars.

NOTE.—The water-tight collar is shaped to fit as shown, and is riveted and caulked in place to ensure water-tight joints or oil-tight joints.
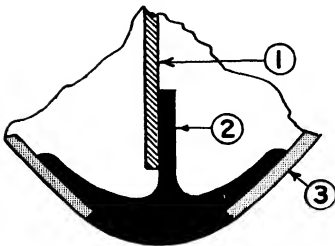
(Vertical Section of bottom after-part.)

1, Vertical keelson.
2, Stem casting.
3, Shell plating.
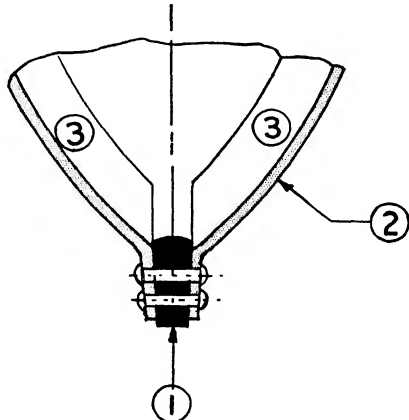
(Horizontal Section at Extreme Forward Position.)

1, Stem bar.
2, Ship plating.
3, Panting stringer.

No. 619.—Cast-steel Stem.
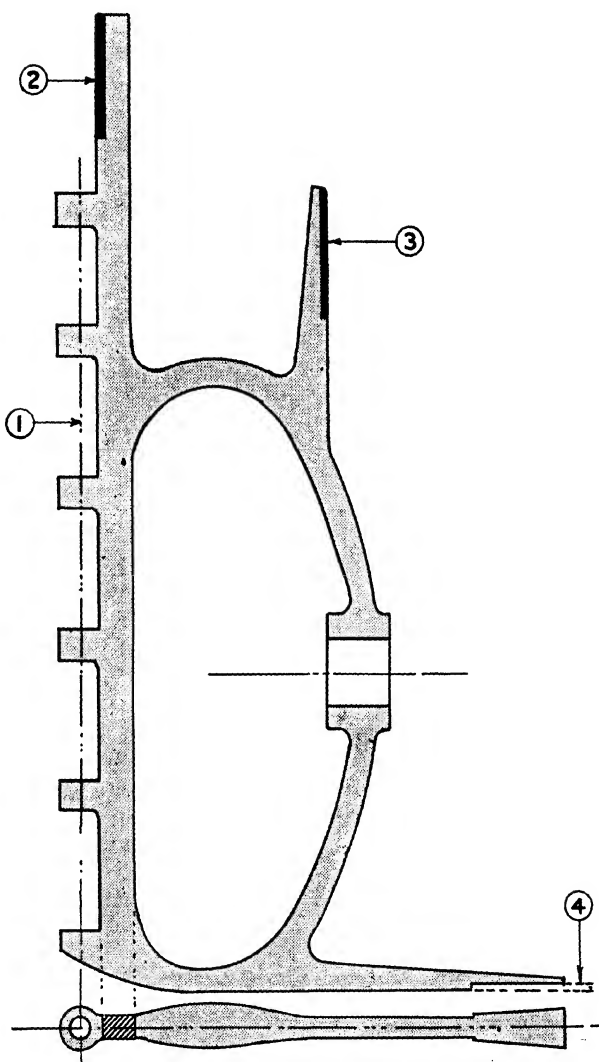
No. 620.—Cast-steel Stern Frame of Single-
screw Steamer.

1, Centre line of rudder post and pintles.
2, 3, Transome floors or beams riveted to frames.
4, Flat keel plate riveted to stern frame foot.
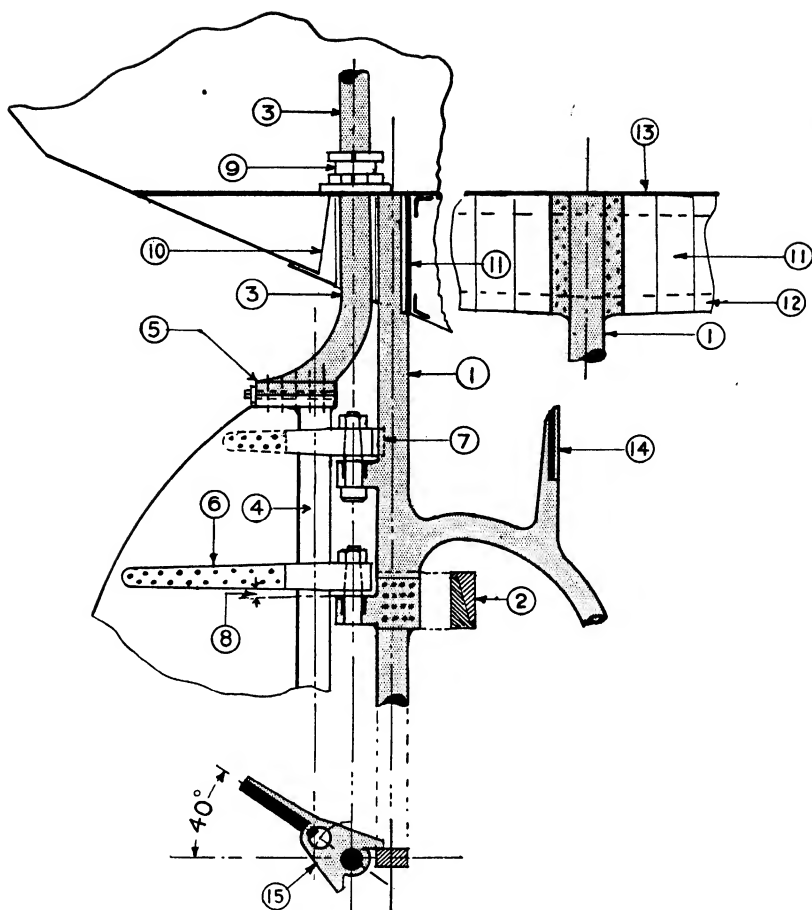
No. 621.—Rudder and Stern Frame.

The stern frame is constructed in two sections which are scarp jointed and riveted together.

1, After stern frame.
2, Scarp joint, machined and quadruple riveted or bolted.
3, Rudder stock.
4, Rudder post.
5, Rudder coupling keyed and bolted.
6, Rudder arm riveted to rudder plate.
7, Rudder stopper, also shown in plan (15).
8, Clearance for wear down=$\frac{3}{4}$ in.
9, Adjustable rudder stock bearing and gland, in halves.
10, Rudder trunk opening.
11, Transome floor, to which the stern frame is securely riveted as shown.
12, Transome frame.
13, Deck plate.
14, Stern frame extension arm riveted to floor.
15, Rudder stopper.

The maximum rudder movement is limited to 40° port or starboard, the steering engine limit stop acting at about 5° less, that is, say, 35° port or starboard.

A good steering-gear engine will produce a full movement from port to starboard position in about thirty seconds or less.
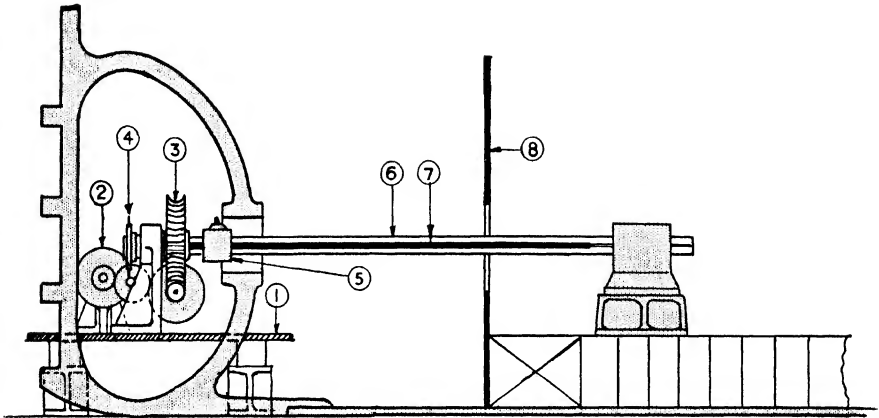
No. 622.—Boring out of Stern Post.*

1, Platform.

2, Electric motor and geared down drive.

3, Worm and worm wheel.

4, Hand or " star " screw feed.

5, Boring head with cutting tool in position.

6, Boring bar.

7, Screw feed.

8, Peak bulkhead.

Also see p. 551 and plates facing p. 1054.

* The above is similar to a sketch by A. C. West which appeared in the *Transactions of the Institute of Marine Engineers* in a paper entitled " Stern Tubes and Tail-end Bearings."
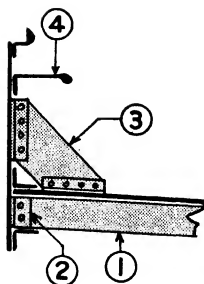
No. 623.—Hatch Coaming.

1, Deck beam.
2, Clip connecting beam with hatch plating.
3, Side bracket.
4, Stiffener.

NOTE.—In some cases web frames are fitted longitudinally at centre and ends of the hatch, and in other cases hold pillars are arranged at the sides of the coaming.
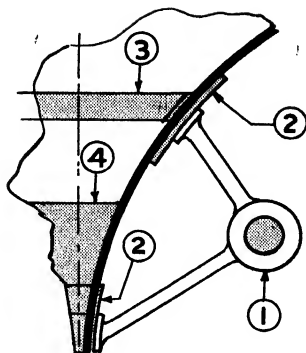
No. 624.—Struts or " A " Brackets of Twin-screw Steamer.

1, " A " bracket.
2, Doubling plates.
3, Cross beam.
4, " Vee " bracket for support.

" Bilge Valves, Cocks, etc.*

(a) The arrangement of valves, etc., should be such as to prevent the possibility of water passing from the sea and from water ballast spaces into the cargo and machinery spaces, or from one compartment to another. To effect this requirement, the bilge connection to any pump having also a suction from the sea should be made by means of either a non-return valve or a cock which cannot be open at the same time to the sea, or to water spaces, and to the bilges. Valves in all bilge distribution-boxes should likewise be of the non-return type, and an approved arrangement of lock-up valves or of blank flanges should be provided to prevent any deep tank being inadvertently run up from the sea when containing cargo, or pumped out through a bilge pipe when containing water ballast, and appropriate explanatory notices should be conspicuously displayed near the fittings involved.

" (b) Provision should also be made to prevent the compartment served by any bilge suction pipe being flooded, in the event of the pipe being severed or otherwise damaged by collision in any other compartment. For this purpose, in cases where the pipe is at any part situated nearer the side of the ship than the extreme outward position permissible for the side of a recess in a bulkhead, there should be fitted to the pipe, in the compartment containing the open end, either a non-return valve or a screw-down valve with an operating rod led up against the bulkhead to a position above the bulkhead deck.

* Extract from Board of Trade Regulations referring to survey of passenger steamers.
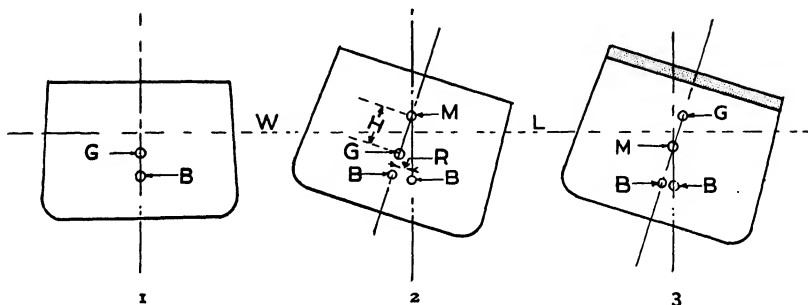
No. 625.—Metacentric Height of a Vessel.

1 shows Equilibrium.
2   ,,   Stability.
3   ,,   Instability.

Centre of Buoyancy (B)=Centre of displaced water volume at the immersed position of the vessel.

Centre of Gravity (G) = Centre of weight of the vessel

Transverse Metacentre (M) = Point at which the vertical centre line from centre of buoyancy intersects the centre line of the vessel when inclined, the horizontal distance between the two being known as the " righting arm " (R).

Distance (H) = Metacentric height.

If the centre of gravity (G) and transverse metacentre (M) exactly coincide when the vessel is inclined the condition will be that of neutral stability or equilibrium. If, however, through, say, loading of deck cargo the centre of gravity (G) rises to a position *above* the metacentre, the vessel will not possess stability or equilibrium and will tend to heel over, the righting arm now being of negative value.

NOTE.—Slack ballast water or bilge water would tend to change the position of the centre of gravity and thus adversely affect the stability of the vessel, so that only one tank at a time should be either filled or pumped out, except perhaps in the case of a deep tank which is fitted with a centre longitudinal W.T. bulkhead.
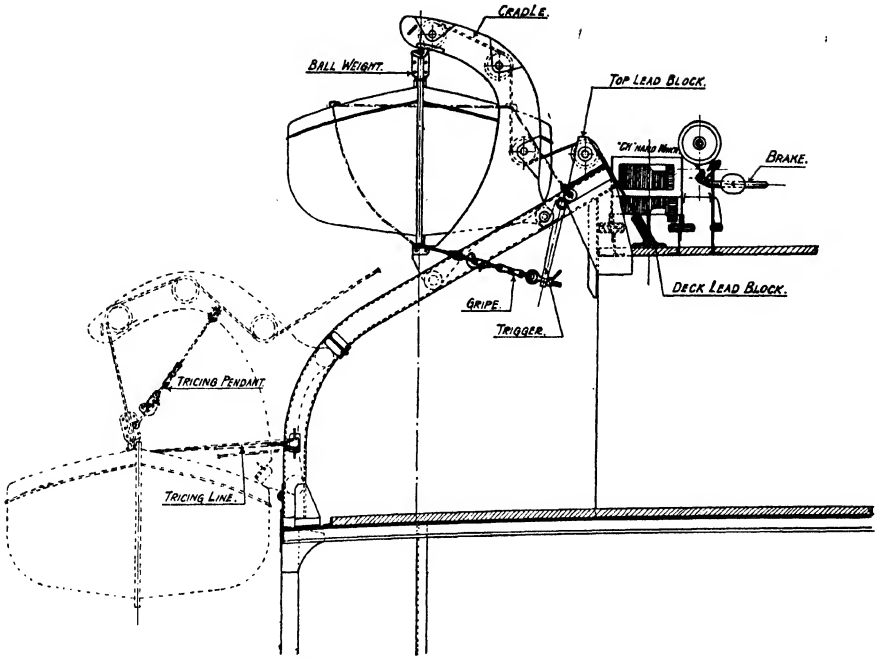
No. 626.—Welin-Maclachlan Davits Ltd. Arrangement of Gravity Davits.

The above view in full lines shows the boat and cradle in the stowed position, while the view in dotted lines shows the cradle over the side with the boat in position for embarking passengers. Each set of davits consists of two cradles fitted with rollers mounted on trackways. The wire falls are led from each cradle to a winch arranged so that the falls run out simultaneously, thus ensuring the boat being dropped into the water on an even keel. The trackways are formed of double channel bars set at a declivity of 30°. The boat is held in the stowed position by means of triggers to which the gripe rope is fastened. The lowering winch is arranged for hand hoisting, but, if required, an electric motor can be fitted to facilitate raising the boats from the water, a clutch being fitted between the motor gearing and the hand gearing.

To Lower a Lifeboat.

1. Drop centre keel support.
2. Release gripe bands (one at each end) and see that triggers are open.
3. Lift winch brake and start flywheel, speed control being effected by hand pressure on brake.

Attentions Required.

To see that the various shaft and drum bearings, cradle rollers, sheaves, deck lead blocks, and trigger pins, etc., are all well packed with a suitable grease, and if an electric motor power shaft is fitted, to have the gear case filled up with oil of reliable quality. The brake requires to be carefully attended to and kept free from rust, the lining of same to be examined periodically.

Electric Motor.

The motors should be fully covered in and kept free of moisture or water. The working parts also require to be covered with oil or vaseline, and the motors should be examined and tested periodically by means of the starter switch for free running, so that in the case of sudden emergency, reliability may be assured. The electric power unit which supplies current to the motors must also be kept in thorough working order.

SECTION XI

THE "STONE" SYSTEM HYDRAULIC CONTROL OF BULKHEAD DOORS

Steam.—The motive power for this system is hydraulic and is obtained from a pair of vertical marine-type steam pumps placed in the engine-room. These pumps are kept constantly under steam, and draw their supply from a tank, force it under a pressure of 700 lbs. per sq. in. to the distributing or master-control valve, two mains from which carry the fluid pressure to each door, while another pipe carries the exhaust to the tank.

Motor.—For motor ships where steam is not available, the hydraulic pressure is obtained from an electric motor-driven rotary pump of sufficient capacity to close all doors, in circuit with an air-loaded accumulator which obtains its air pressure from the air reserve for starting the main engines. In this instance the air accumulator being under constant load has a reserve of power, so that if the pump is stopped it can operate the doors three times, *i.e.*, close them twice and open them once, before the pressure in the air accumulator becomes ineffective. The pump is controlled hydraulically for continuous running, and electrically by a pressure switch for intermittent running, so arranged that when the pressure in the mains falls below a pre-determined figure the pump is started to recharge the accumulator to the normal pressure, *i.e.*, 700 lbs. per sq. in.

A branch from each main is connected to the control valve at each door, connections to the ends of the door-operating cylinder being made from the valve. On operating the master-control valve from the bridge, by means of the bridge-control valve, one main is connected to pressure from the pumps, and the other is connected so as to exhaust to the tank. By reversal of the master-control valve, the conditions of pressure and exhaust in the two mains are reversed, causing in one direction of flow " closing control," *i.e.*, the closing of the doors, and in the other causing " normal control," *i.e.*, the opening of the doors. This latter action drives the door-control valves to a neutral position if they are permanently arranged to prevent opening from the bridge.

In order to permit local control of each door, there is fitted, in the pipes between the mains and the door cylinder, a door-control valve which allows the door to be operated at will, irrespective of the bridge control, but is so designed that when the latter control is at " close all doors," or " closing control," the door will only remain open as long as the valve lever is operated against such control.

It is possible, by varying certain parts of the door-control valve, to prevent the bridge control opening any particular door or group

922
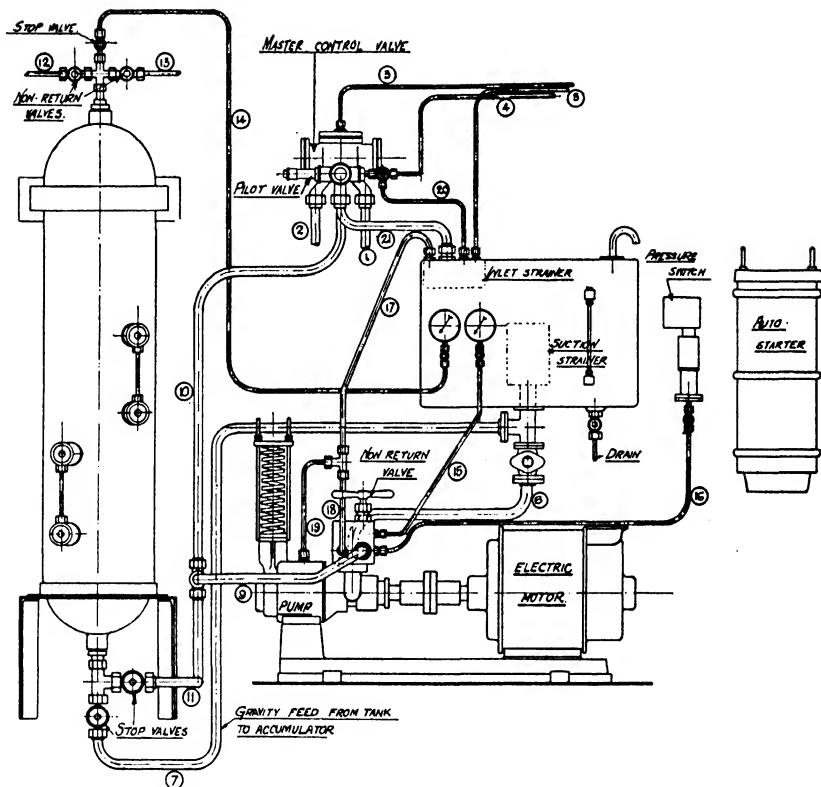
No. 627.—" Stone " System of Water-tight Bulkhead Doors.

(Power unit for motorships where steam is not available.)

No. 628.—" Stone " Water-tight Door System.

Showing general arrangement of a horizontal sliding door and a vertical sliding door, etc.

of doors, or even to keep it or them permanently closed, without affecting the action of others ; this point is important—for instance, in the case of refrigerator room and some bunker doors.

To remove all water-lock in the door-operating cylinders when power is not available, a by-pass valve is fitted at each door, so that whenever pressure is removed from the system or from any door, this valve automatically opens up communication between the two ends of the cylinders ; the re-entry of pressure closes this by-pass valve.

The master-control valve consists of a ram-operated slide valve, which reverses the conditions of pressure and exhaust in mains 1 and 2, and which is controlled by a pilot valve, as follows :—

One end of the ram of this pilot valve is loaded by a spring which always tends to move the valve to the closing position. When, however, pressure is admitted to the other end of the ram by operation of the bridge control, it overcomes the closing tendency of the spring, and moves the valve to the opening position. On the release of this pressure the spring automatically returns the valve to the closing position.

The pilot-valve ram is connected by a $\frac{1}{4}$-in. pipe to the pressure branch of the bridge-control valve, from which its operating pressure supply comes. This, firstly, is taken by a $\frac{1}{4}$-in. pipe from the main pressure chamber of the master-control valve, while a $\frac{1}{4}$-in. exhaust pipe from the bridge-control valve is led back to the supply tank.

The bridge control is a combination of a spindle-operated slide valve, an electric switch together with an electric warning, and a power indicator. When closing control (i.e., close all doors) becomes necessary, a handle is rotated ; this closes the switch, causing an electric bell near each door to ring for a predetermined period. That these electric bells are in operation is shown by the electric warning indicator lighting up. On the cessation of the bells ringing, the spindle of the slide valve is engaged, and the valve is pushed over to the closing control position. As previously described, this operation reverses the master-control valve, thus reversing the conditions of pressure and exhaust in mains 1 and 2, and the doors close, the power indicator on the bridge showing that pressure is available.

Referring to the diagrams attached, when the master-control valve allows pressure to pass into main No. 1 and allows main No. 2 to exhaust to the tank, the pressure passes on to the back of each slide valve in the door-control valve and passes through to the opening end of the cylinder, the closing end exhausting into the door-control valve casing through main No. 2 to the tank, *opening the doors* (*vide* Diagram No. 1).

FROM PUMPS

MASTER CONTROL VALVE.

TO TANK

CLOSING END

No 2   No 1

HYDRAULIC CYLINDER

'C'

OPENING END

B
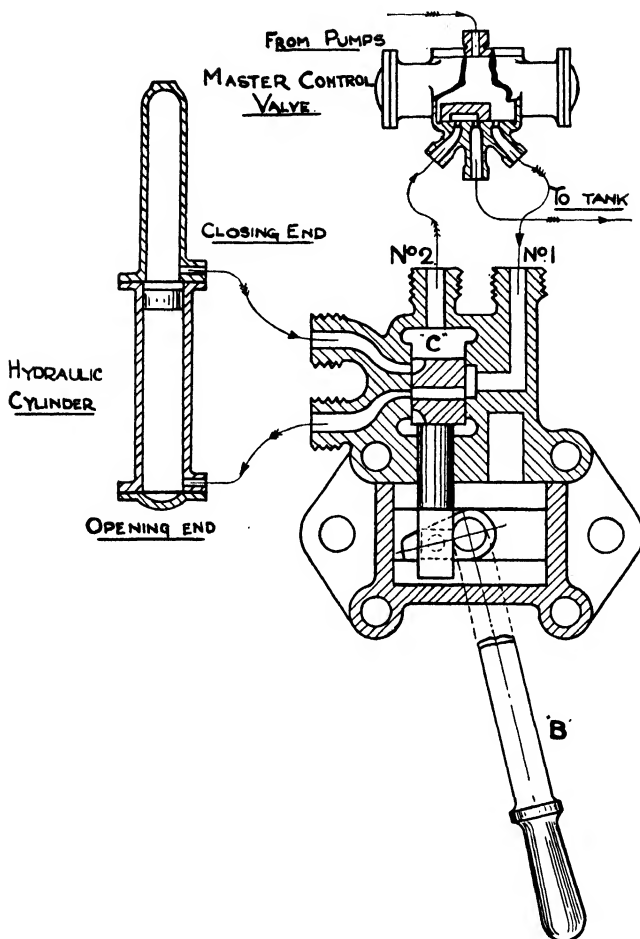
" Stone " Door System.

Diagram No. 1.—All Doors Open Simultaneously.
(Normal Control.)

Note.—The " Master-Control Valve " referred to is situated on the bridge.

To Close the Door Locally.—The slide valve in the door-control valve is reversed by the lever B, allowing pressure to flow from main No. 1 through the slide valve to the closing end of the door cylinder, the opening end exhausting through main No. 2 to the tank (*vide* Diagram No. 2).

FROM PUMPS.

MASTER CONTROL
VALVE.

TO TANK

CLOSING END

HYDRAULIC
CYLINDER.

N°2   N°1

C

OPENING END.

B
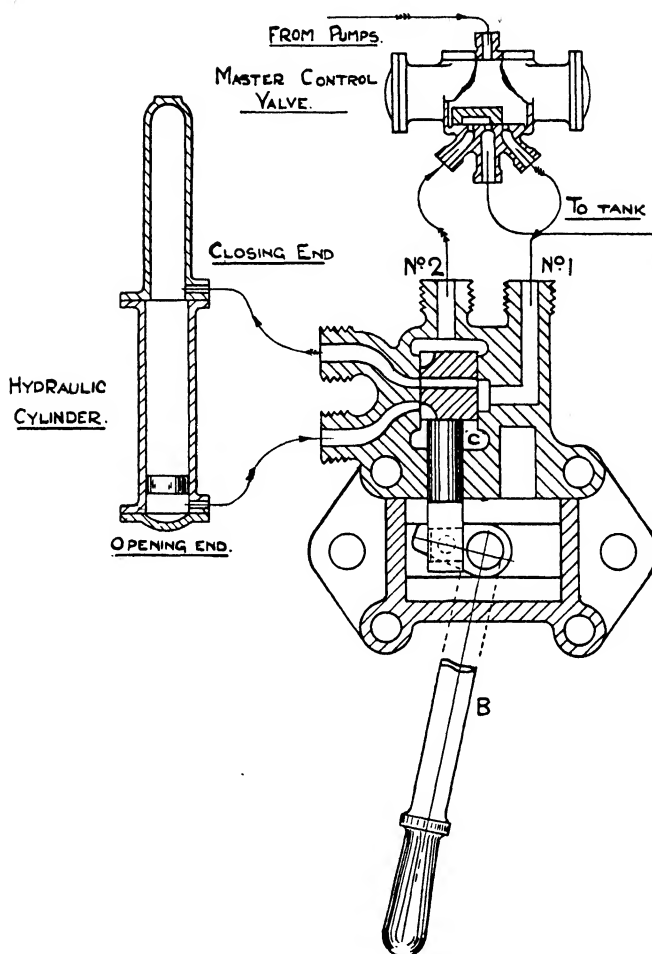
" Stone " Door System.

Diagram No. 2.—Doors Closed Locally.

(Normal Control.)

To Stop the Door.—The slide valve is brought to the " mid " position, cutting off pressure from both ends of the door cylinder (*vide* Diagram No. 3).

If, now, the master-control valve is reversed, main No. 1 is allowed to exhaust to the tank and pressure passes from the pumps to main No. 2 and, entering the central part of the door-control
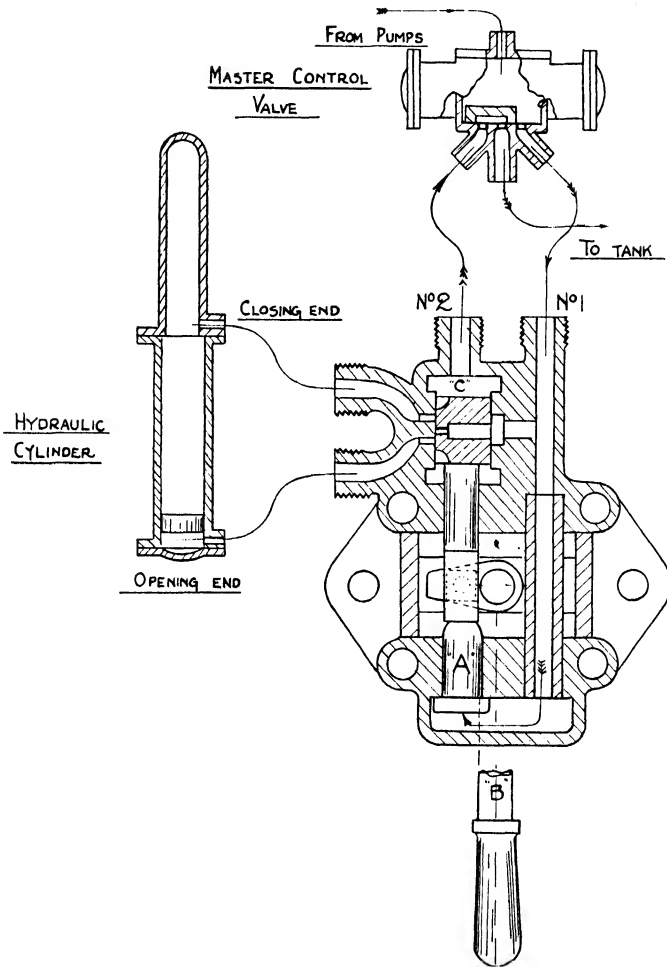
" Stone " Door System.

Diagram No. 3.—Door Stopped in Intermediate Position.

(Normal Control.)

valve casing, acts on the area of the spindle C therein, forcing the latter downwards if the slide valve has been previously raised. The pressure then passes to the closing end of the door cylinder, the opening end exhausting by way of main No. 1 to the tank. Thus all doors close irrespective of the position in which they may have been left (*vide* Diagram No. 4).

FROM PUMPS

MASTER CONTROL VALVE

TO TANK.

CLOSING END.   N°2.   N°1.

HYDRAULIC CYLINDER

'C'

OPENING END

B
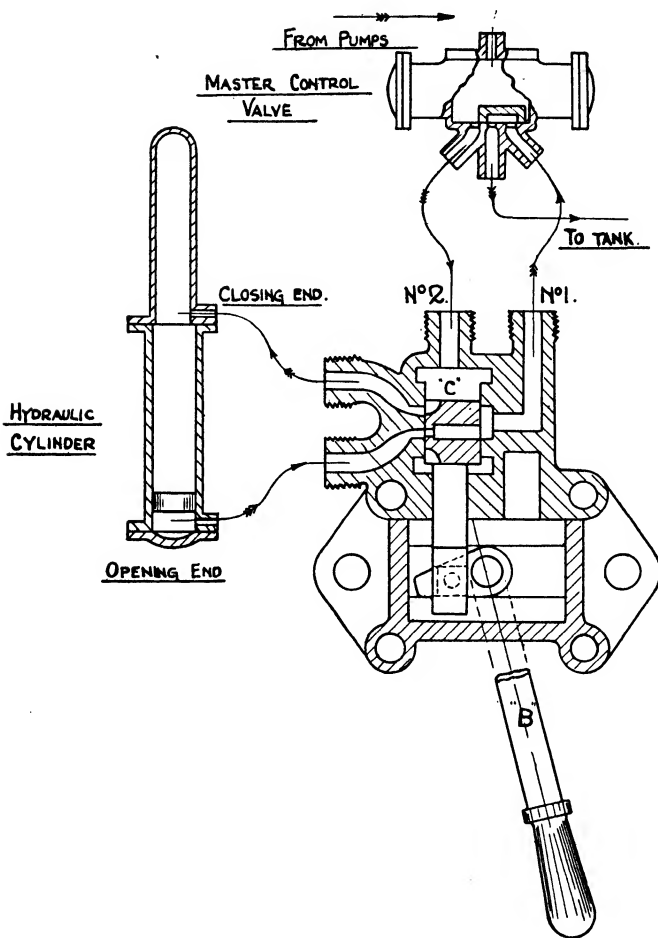
"Stone" Door System.

Diagram No. 4.—Doors Close Simultaneously.

(Emergency Control.)

To Open the Door Locally.—Reverse the slide valve by means of the lever against the pressure load on the spindle C. Pressure then passes to the opening end of the cylinder, the closing end exhausting into main No. 1 (*vide* Diagram No. 5). On the release of the handle, the pressure in main No. 2 acting on the area of the spindle C forces the slide valve downwards, and the door recloses (*vide* Diagram No. 4).

FROM PUMPS

MASTER CONTROL
VALVE

TO TANK

CLOSING END

N°2   N°1

HYDRAULIC
CYLINDER

C

OPENING END

B
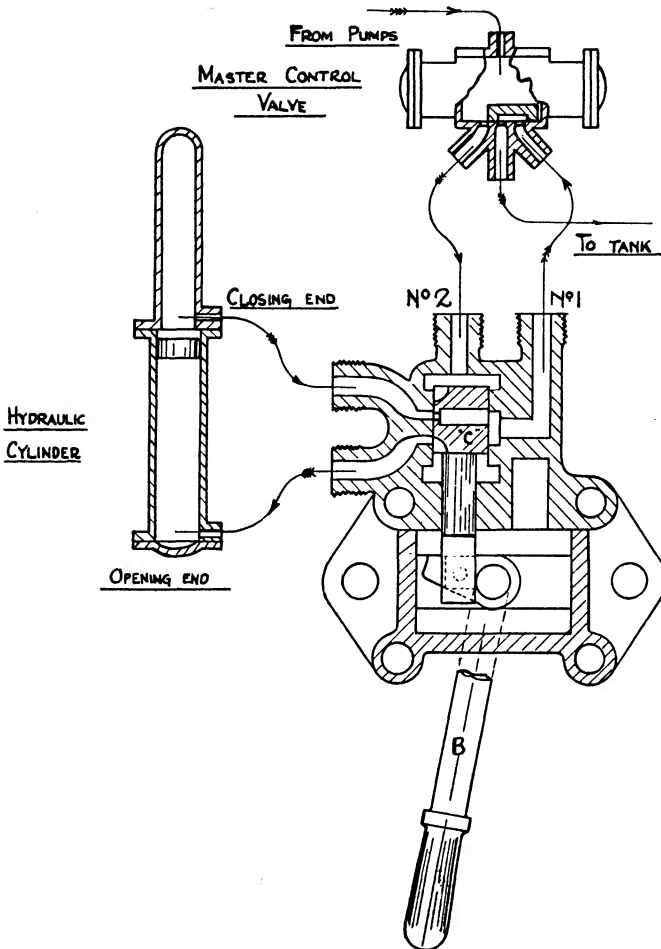
" Stone " Door System.

Diagram No. 5.—Door Opened Locally.

(Emergency Control.)

For doors which it is not desirable to open from the bridge a small plunger A is fitted in the door-control valve casing in communication with main No. 1, so that pressure coming therefrom raises the plunger, and the end of which, bearing on the valve-operating lever B, raises the slide valve to the " mid " position, preventing the entry of pressure to either end of the door cylinder,

FROM PUMPS

MASTER CONTROL
VALVE.

TO TANK.

CLOSING END.   N° 2   N° 1.

HYDRAULIC
CYLINDER.

C

OPENING END.

B
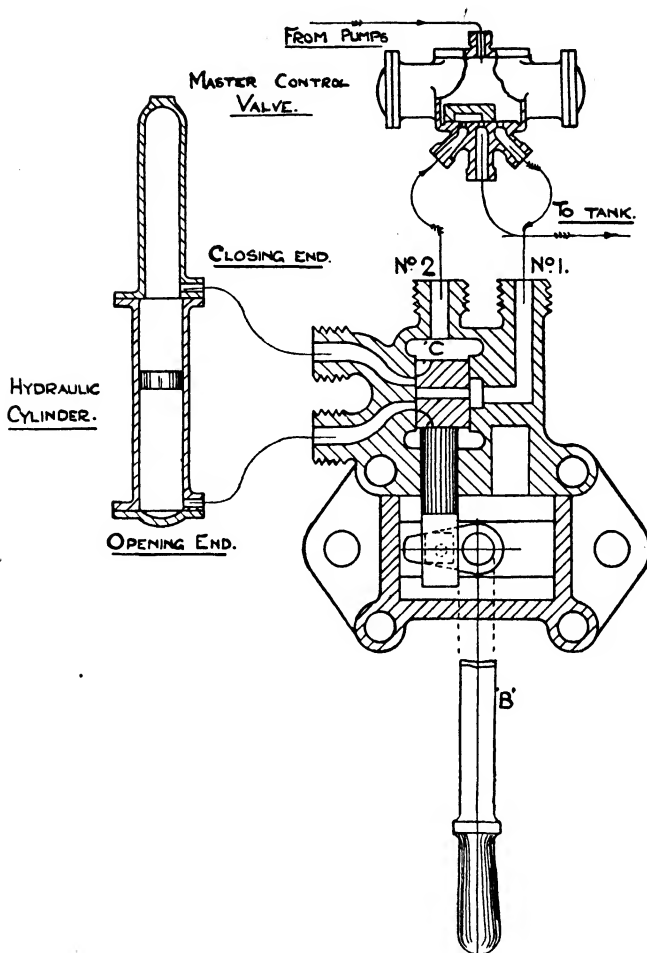
"Stone" Door System.

Diagram No. 6.—Door Remains Closed.

(Normal Control.)

and the *door remains closed* (*vide* Diagram No. 6). The door
may still be opened locally, as on operating the lever against the
effort of the plunger A the slide valve is lowered, causing the
opening of the door (*vide* Diagram No. 7). On the release of
the lever B the plunger A returns the slide valve to the "mid"
position, and the door remains in the position left, whether open,

FROM PUMPS

MASTER CONTROL
VALVE.

TO TANK.

CLOSING END

N° 2   N° 1

HYDRAULIC
CYLINDER

'C'

OPENING END.

A

B
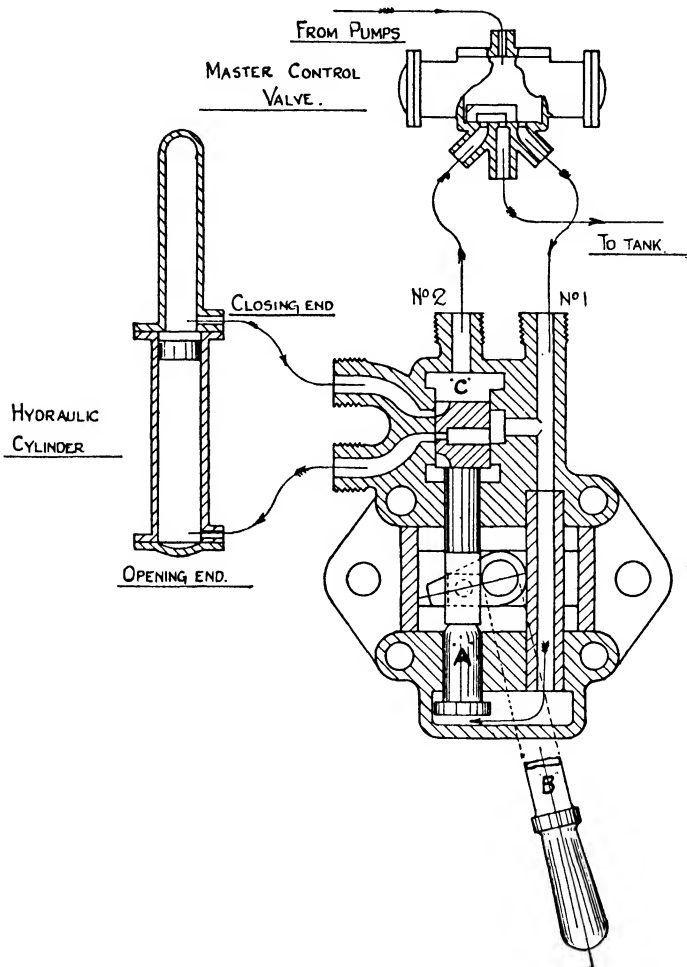
" Stone " Door System.

Diagram No. 7.—Door Opened Locally.

(Normal Control.)

partly open, or closed, until the next closing control from the bridge, or until locally operated. Admission of pressure into main No. 2 moves the valve to the closing position, main No. 1 being now exhausted, the plunger A offering no resistance to the rise of the lever B (*vide* Diagram No. 8).

On the bridge an electrical indicator is fitted; this has an

FROM PUMPS

MASTER CONTROL VALVE.

TO TANK

HYDRAULIC CYLINDER

CLOSING END.

OPENING END

No. 2.

No. 1

C

A

B
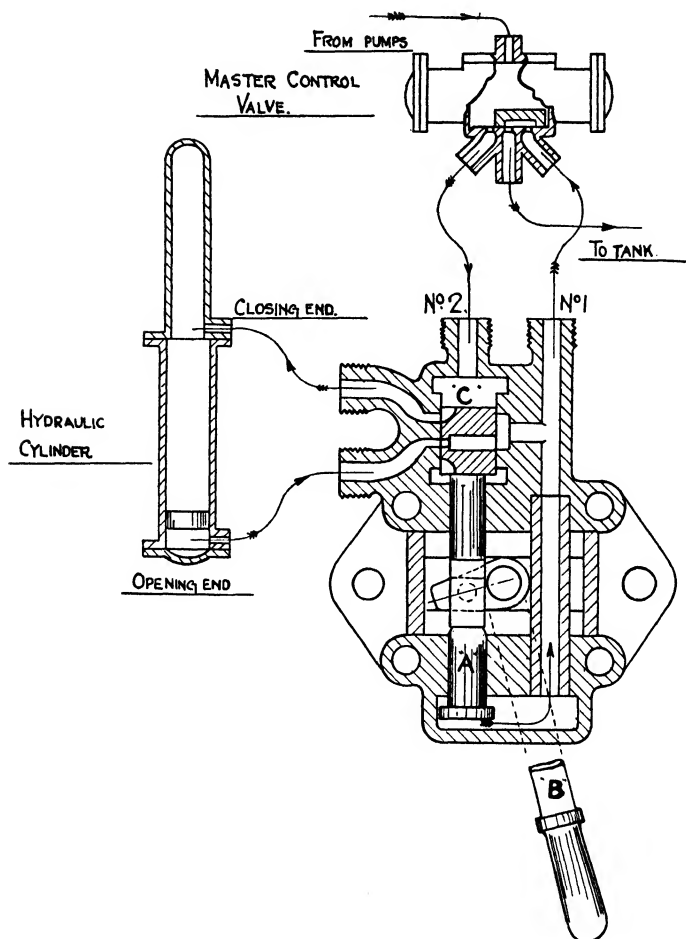
"Stone" Door System.

Diagram No. 8.—Doors Close Simultaneously.

(Emergency Control.)

engraved plan of the ship showing, by numbered glass discs, the actual positions of the doors. As doors close, the electric circuits to their corresponding lamps are completed, and the discs on the indicator are illuminated. Thus it can be seen at once whether any door is operating properly or not.

Two warning bells are fitted with each door; one, electrical,

which rings for a predetermined period before the door starts to close, and the other, mechanical, which continues to ring during the whole time the door is closing.
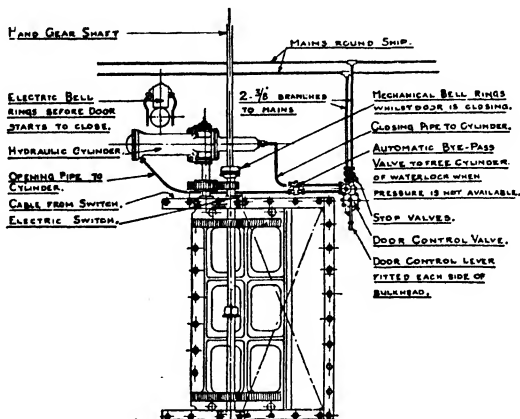
Typical Arrangement of the "Stone" Horizontal Sliding Water-tight Door.
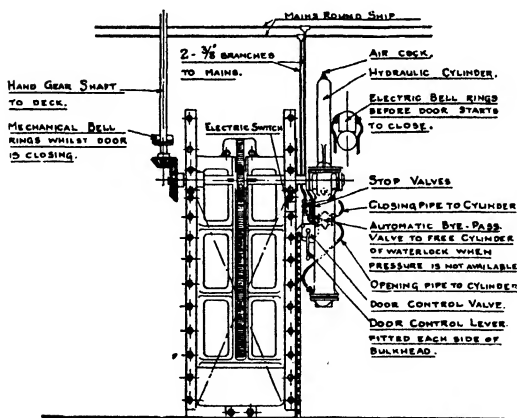
Typical Arrangement of the "Stone" Vertical Sliding Water-tight Door.

SECTION XII.

GENERAL ELECTRICAL NOTES AND SKETCHES.

By "**potential**" is meant the difference of electrical tension existing between the positive and negative leads.

A **volt** is the measure of electrical pressure or E.M.F. (Electro-Motive Force).

Or, A volt is the E.M.F. required to give one ampere of current against one ohm resistance.

An **ampere** is the measure of electrical current, and is taken as the standard flow of electricity in a wire per second, or, the current flow required to deposit $1 \cdot 118$ milligrams of silver in one second.

An **ohm** is the measure of electrical resistance, and is about equal to that of one mile of copper wire $\frac{1}{4}$ in. in diameter, or is equal to the resistance offered by a column of mercury $106 \cdot 3$ cm. in height and 1 sq. mm. in sectional area at a temperature of $32°$ F.

Volts × Amperes = Watts ; also, Amps.^{2} × Ohms. = Watts.

746 watts are equal to 1 **electrical horse power.**

Therefore, $$\frac{\text{Volts} \times \text{Amperes}}{746} = \text{E.H.P.}$$

E.H.P. compared to I.H.P.

It should be noted that the electrical horse power refers to *one second* of time, as the ampere flow is measured for that period, whereas the I.H.P. of steam refers to one minute of time.

Therefore, $33000 \div 60 = 550$ ft.-lbs. per sec.

And, 746 watts $= 550$ ft.-lbs.

So that, $746 \div 550 = 1 \cdot 35$ watts per ft.-lb.

As work and heat are equivalent, then it can be proved that to produce the same heating effect (energy), $1 \cdot 35$ watts are equal to 1 ft.-lb.

E.H.P. per minute $= 746 \times 60 = 44760$ watts per min.

The **size of a wire** depends on the amount of current it has to carry ; in other words, on the number of amperes.

The **insulation of a wire** depends more on the number of volts carried by the wire.

The Board of Trade limit is 1000 amperes per sq. in. of wire section.

Fuses or **cut-outs** are constructed to melt when the current becomes double the working current.

Insulating materials are composed of indiarubber, tape, varnish vulcanised fibre, glass, cotton, earthenware, etc.

Arc lamps are usually run at from 45 to 55 volts.

Arc lamps require from 8 to 12 amperes of current.

Projector arc lamps require from 80 to 150 amperes of current.

A 16 candle-power incandescent carbon filament lamp requires about 60 watts.

A 16 candle-power incandescent lamp run at 75 volts requires ·8 of an ampere, because 60 watts ÷ 75 volts = ·8 of an ampere.

An " Osram " 16 candle-power incandescent metallic filament lamp only requires about 20 watts, as the resistance of the filament is higher and requires less current to produce the same heat.

1000 watts are equal to **1 kilowatt.**

The **positive** bar or terminal is often marked thus +, and painted red.

The **negative** bar or terminal is often marked thus —, and painted blue.

The equaliser bar is usually painted yellow.

Fuses in earthenware cases are placed at different parts of the wire circuits to act, if required, as automatic circuit-breakers.

Dynamos for ship-lighting usually develop from 110 to 220 volts.

" In series " means in continuation.

" In shunt " means branched off.

Continuous current dynamos are generally employed for lighting purposes, and alternating current dynamos for power stations.

Transformers are used in power stations to reduce the current from a high to a low voltage without serious loss.

100 amperes at 2000 volts will give 400 amperes at 500 volts if a transformer is used, because

$$\frac{\overset{\text{Amperes.}}{100} \times \overset{\text{Volts.}}{2000}}{\underset{\text{volts.}}{500}} = 400 \text{ amperes.}$$

Note.—This neglects loss of efficiency in transformer.

Accumulators are used for the storage of electricity, and consist of a number of galvanic cells joined in series. The cells are charged by the current from a dynamo, which decomposes the acid bath of the cells and reverses the chemical conditions. After charging, the electricity so stored up may be released and employed to act on an external circuit if suitable wiring is arranged, as the chemical relation of the plates causes a return to their original condition. Accumulators are often employed on yachts, where a small number of lamps may be required during the night, and in cases where the dynamo is not kept running constantly.

An **electrolyte** is a salt or a solution of fresh water and sulphuric acid which is decomposed on the passage of a current through it.

An **anode** is a terminal plate or rod, etc., by which the current enters the electrolyte.

A **kathode** is a terminal plate or rod, etc., by which the current leaves the electrolyte.

The **anode** and **kathode** are referred to as electrodes.

The quantity of current flowing past a one ampere section of wire in one second is called a " **coulomb.** "

Electricity is one form of " energy " or " force."

Induction is the magnetic or electrical effect produced on surrounding bodies or substances by an electric current.

The principle of induction is employed in transformers, where a current of high voltage in a set of fine wires is made to induce currents of a lower voltage in a set of coarser wires.

One **megohm** is equal to 1000000 ohms, and is used for measuring the resistance of insulating materials.

All substances offer more or less resistance to the flow of an electric current : those having least resistance are employed as " **conductors,** " and those having most resistance are employed as " **insulators.** "

Electric cables are usually composed of several wires covered with non-conducting material. Their size is rated by combining the number of wires with the S.W.G. number, thus 5/22, meaning 5 wires each of No. 22 Standard Wire Gauge.

Rules—

To find the **current strength** in amperes passing through an electrical circuit

Rule—
$$\frac{\text{Volts}}{\text{Ohms resistance}} = \text{Amperes,}$$

and,
$$\frac{\text{Volts}}{\text{Amperes}} = \text{Ohms,}$$

or,
$$\text{Amperes} \times \text{Ohms} = \text{Volts.}$$

Example 1.—The voltage is 100, and the resistance of a 16 candle-power lamp 220 ohms.   Find the required current in amperes

Then, $\text{Amperes} = \dfrac{\text{Volts}}{\text{Ohms}} = \dfrac{100}{220} = \cdot45$ ampere.

Example 2.—Find the resistance in ohms if the voltage is 100 and the amperes 300.

Then, $\text{Ohms} = \dfrac{\text{Volts}}{\text{Amperes}} = \dfrac{100}{300} = \cdot33$ ohm.

Example 3.—The output in amperes is 250, and the resistance ·4 ohm.   Find the required voltage.

Then, $\text{Volts} = \text{Amperes} \times \text{Ohms} = 250 \times \cdot4 = 100$ volts.

Example 4.—Find the number of watts required for a lamp taking ·6 of an ampere at 100 volts.

Then, $\text{Watts} = \text{Volts} \times \text{Amperes} = 100 \times \cdot6 = 60$ watts.

Practical Operation of Electrical Generators.

The dynamo should always be placed in a cool part of the engine-room, as the insulation is likely to suffer should the temperature rise unduly, and unless specially designed, no dynamo should run with a temperature above 180° F.   The air passages in the armature should be kept clean and free from oily dust deposit usually found in these passages.   The regular use of a pair of bellows will help to keep this part of the machine in good order, and thereby lead to a cooler running generator.

A loose or bad connection in the field circuit will usually be the reason for a dynamo, which has run all right, failing to excite.   If this should happen after a repair, it might be caused by a mistake in the connection of the armature or field circuit, or the brushes might require moving a little.

Should the polarity of a dynamo be accidentally reversed, this can usually be cured by stopping the machine, lifting all brushes clear of the commutator, closing the main switch and opening it again, but as slowly as possible.

Sparking and a commutator marked in patches is usually caused by one of the following: (1) Defective joint of winding to commutator ; (2) armature out of balance ; (3) commutator requiring truing up.

Heavy sparking and one segment of commutator badly marked is nearly always caused by a broken winding in the circuit in connection with that segment, or else the armature insulation is defective and shorting to earth.

Principles of Electrical Magnetism, Etc.
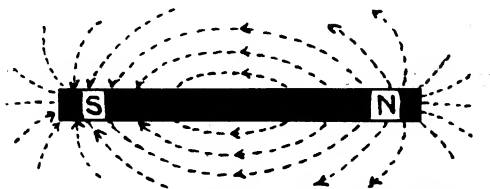
No. 629.—Lines of Force in a Bar Magnet.

Lines of force flow from N. to S. poles as shown by the arrows and dotted lines.
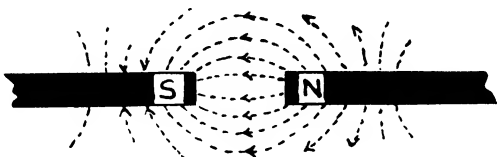
No. .630—Lines of Force Between Two Bar Magnets.

Notice that when the N. pole of one magnet and the S. pole of another are brought together lines of force pass out from the N. pole to that of the other S. pole, that is, " unlike poles attract."
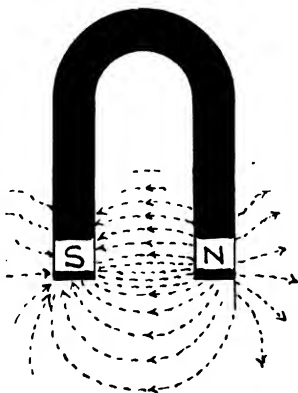
No. 631.—Horse Shoe Magnet.

As in the case of the bar magnet, lines of force pass over from the N. pole to the S. pole, the gap between being known as the " field space " or " magnetic field." A two-pole dynamo is similar to the above, the armature revolving in the space between the two magnet poles.
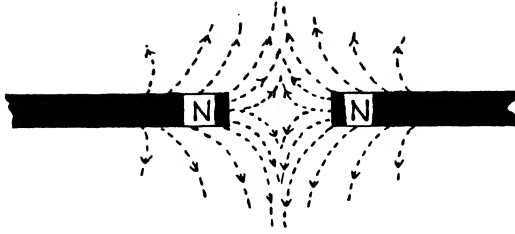
No. 632.—Opposed Magnetism.

Two bar magnets placed as shown, with like poles to like, produce repulsion of the lines of force, as, " like poles repel " and " unlike poles attract."
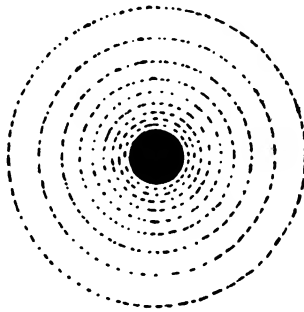
No. 633.—Lines of Force Surrounding a Conductor.

A live wire is encircled by lines of force as indicated by the dotted circles. From these are obtained the induction effects, which develop between adjacent coils under certain electrical conditions.
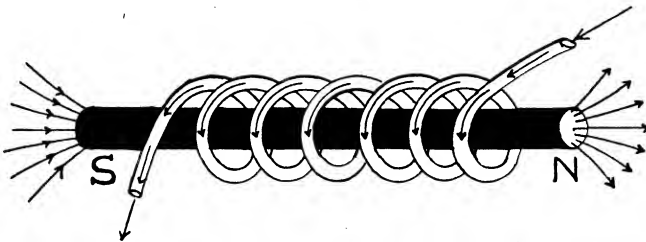
No. 634.—Electro-Magnet.

By coiling a wire round a bar of iron as shown, and passing a current through the wire, the bar becomes magnetised. The flow of current in the wire, polarity, and the lines of force produced in the bar are clearly shown by the arrows.
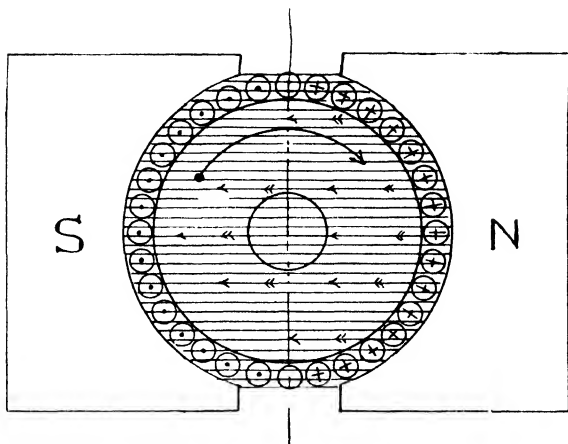
No. 635.

Diagram showing lines of force across field space, when un-disturbed by armature magnetism. The position of the brushes would in this case be exactly at the top and bottom of the com-mutator circle.

The dots on the conductor ends represent positive E.M.F.
,, **crosses** ,, ,, ,, **negative** ,,
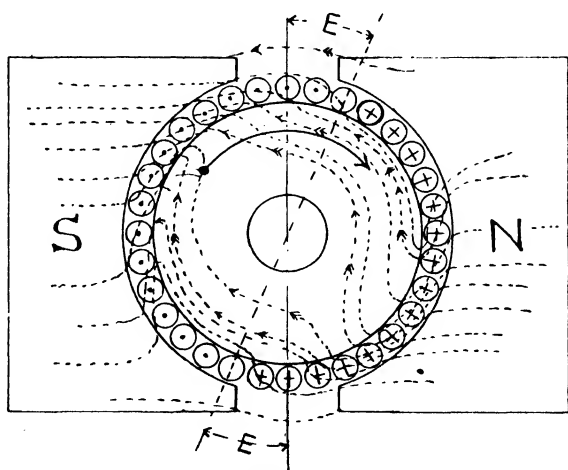
No. 636.

Diagram showing lines of force across field space as affected by armature magnetism. It will here be seen that the lines of force

are now distorted by the effect of the armature acting as a magnet, thus pulling round the field lines in the direction of rotation, so that to strike the neutral point or sparkless position for the brushes when the load is increased, the latter require to be rocked round slightly in the direction of rotation (advanced). For an electric motor, as the E.M.F. action is reversed, the brushes require to be moved back in place of forward.

To correct this distortion of the field, dynamos are now usually fitted with " commutator poles " (see sketch No. 647), which neutralise the effect of the armature magnetism, and eliminate the necessity for altering the position of the brushes when the load or speed is increased.
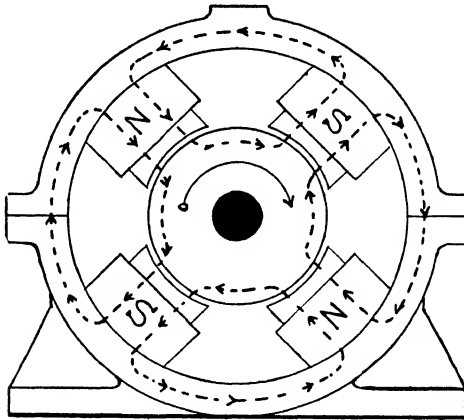
No.638 .—Lines of Force in 4-Pole Dynamo.

The arrows show the direction of the lines of force between the poles of a 4-pole machine, the armature running clockwise. The armature conductors cut through these lines of force and generate currents by induction.
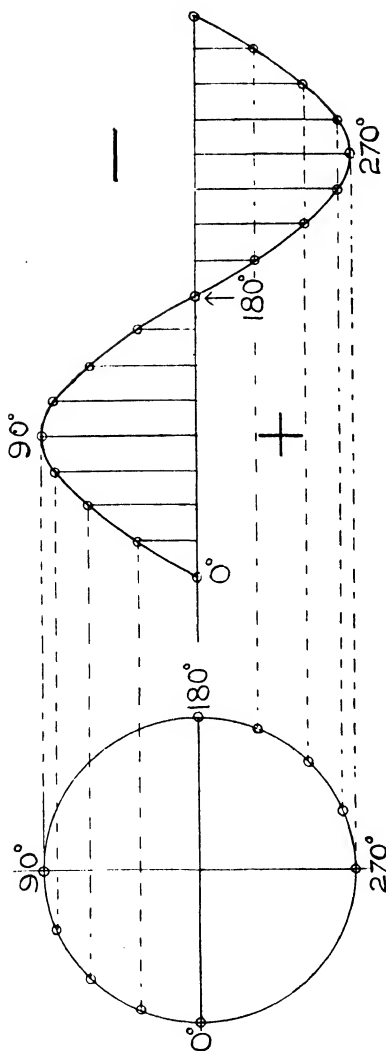
No. 639.—E.M.F. Alternation Curve of 2-Pole Dynamo.

In a 2-pole dynamo the E.M.F. alternates twice per revolution, and is represented as rising for positive and falling for negative.

The diagram shows what is called a " sine wave," and illustrates the variation of the current E.M.F. at different positions of the circle or revolution. At 0° the E.M.F. is at zero, at 90° the E.M.F. is at a maximum positive; at 180° it drops to zero again, at 270° it reaches a maximum negative, and back at 0° it again comes to zero.

The vertical division lines and the dotted horizontal lines show how the curve is developed.

To change these alternations into direct flow or continuous current a commutator becomes necessary. The number of alternations occurring per second is called the " frequency."
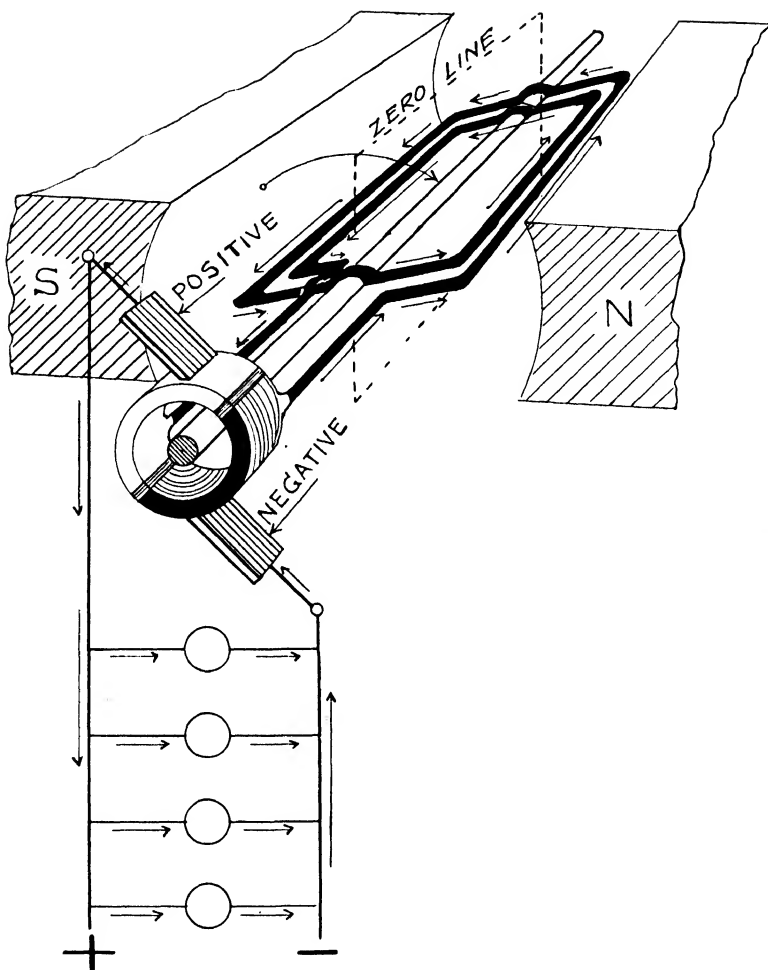
No. 640.—Simple D.C. Armature Conductor
(with one conductor and two commutator bars).

The conductor, it will be noticed, is wound back on itself, and this is done to intensify the E.M.F. effect by increasing the number of turns or loops formed by the conductors, the effect being cumulative. The arrows show that the current flow is in one direction, from left to right through the lamps and back again. At present position the shaded commutator bar is negative and the light one (left) positive.
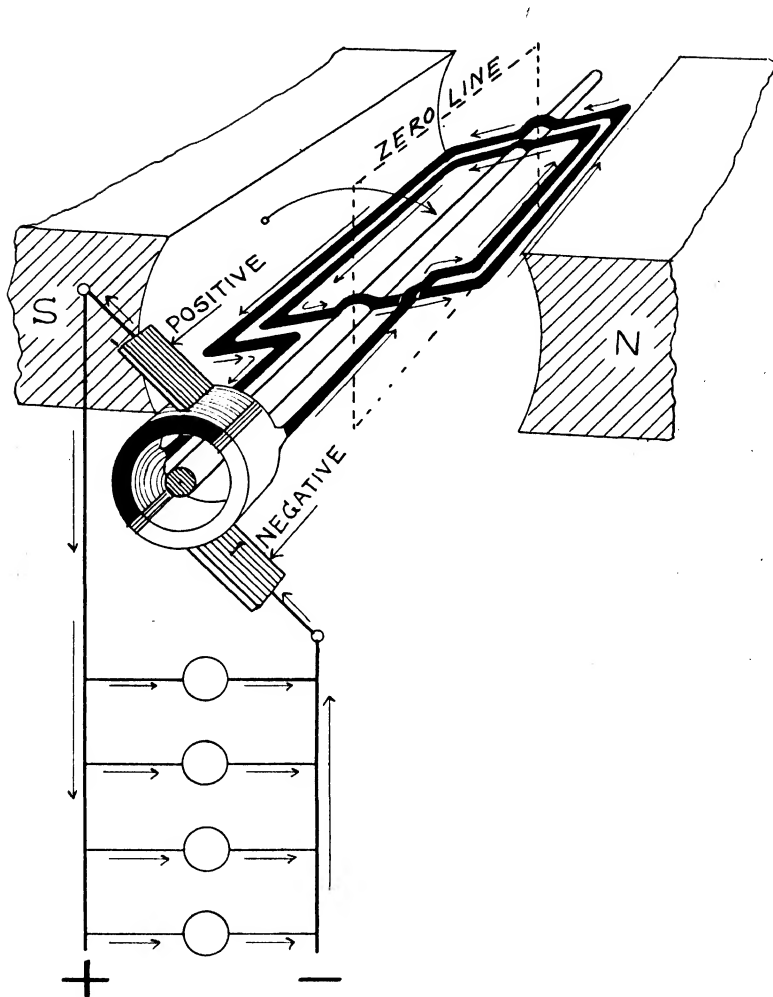
No. 641.—Simple D.C. Armature Conductor.

After making a half revolution it will be noticed that the current is still flowing in the same direction, as the dark commutator bar is now under the positive brush, and thus counteracts the reversal of current flow in the conductor. By this means the current is " commuted " to flow in one direction all the time.
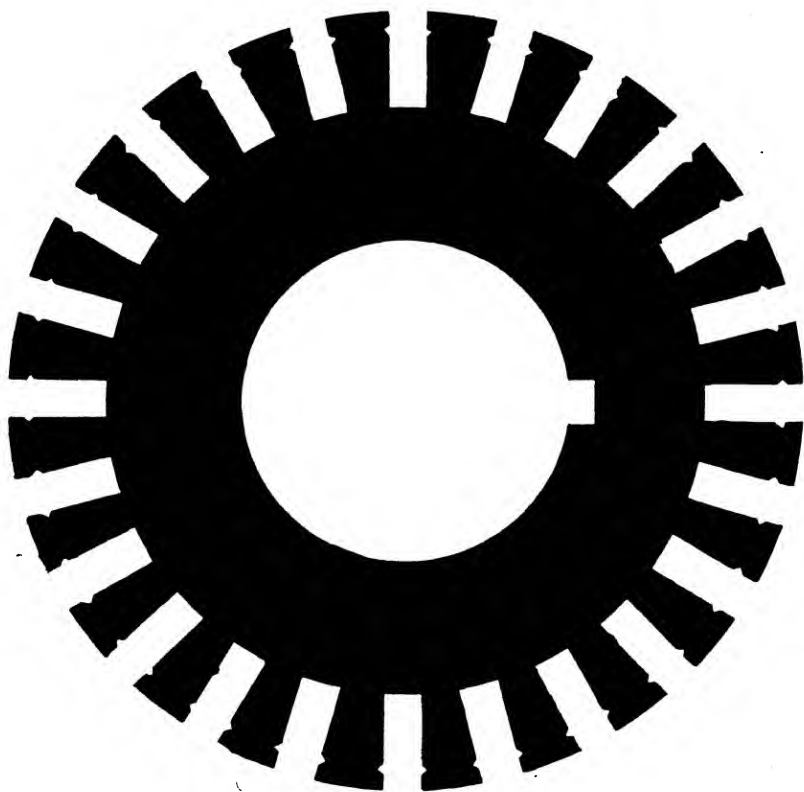
No. 642.—Soft Iron Disc of Armature Body.

The armature is built up with a number of these plates formed of soft charcoal iron, insulated from each other by thick varnishing, and clamped on endways to the driving spindle, spider, and key. The slots shown are for the insulated conductors, which are held in place by check pieces and by binding straps.
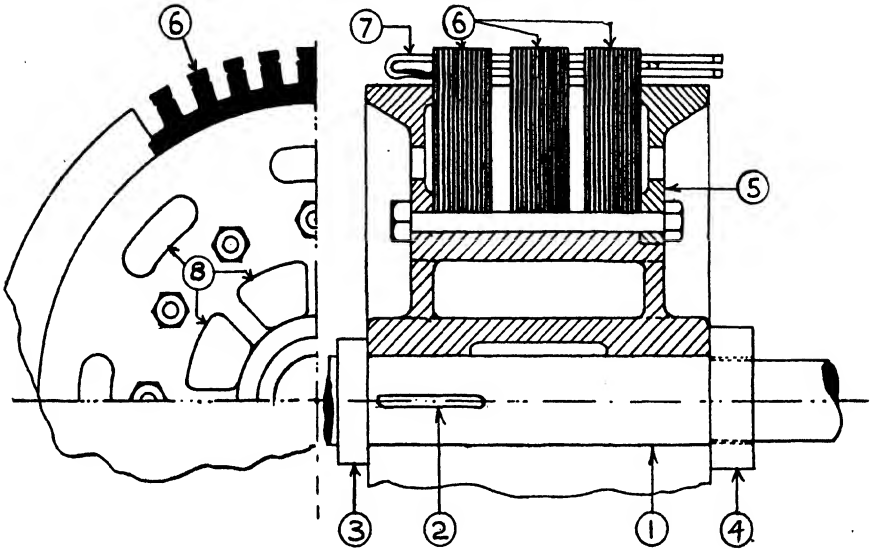
No. 643.—Sectional View of Armature.

1, Driving shaft.   2, Feather or key.   3, Collar.
4, Nut.   5, Locking plate.

6, Plates of soft iron insulated from each other by varnish, and which form the " armature core." The insulating of each plate from the next prevents the formation of eddy currents in the armature body, without in any way interfering with the flow of lines of force across the poles.

7, Conductor lying in longitudinal slotway, and connected up to the commutator bars by either the " wave " or " lap " wound system of winding.

8, Ventilation openings to prevent rise of temperature.
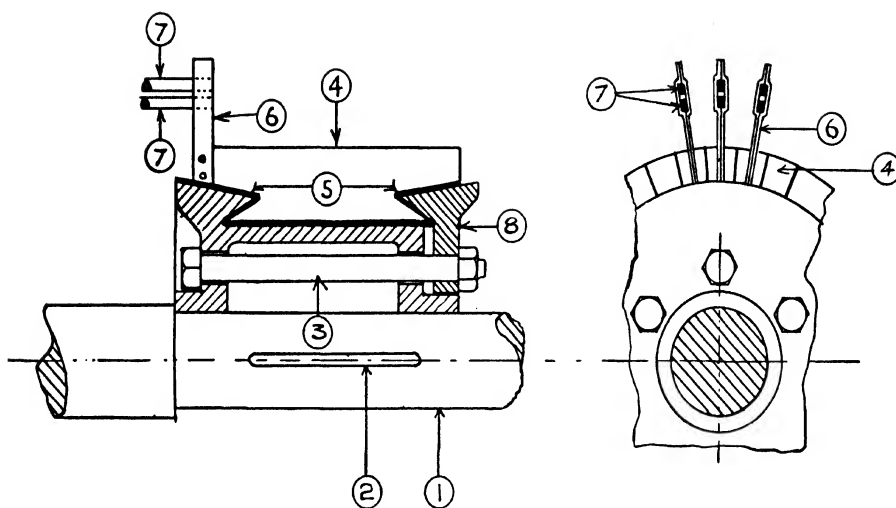
No. 644.—Sectional View of Commutator.

1, Driving shaft.
2, Feather or key.
3, Bolt for clamping copper blocks in position.
4, Copper bar.
5, Insulation.
6, Connector for conductor and copper block.
7, Armature conductor.
8, Locking clamp.
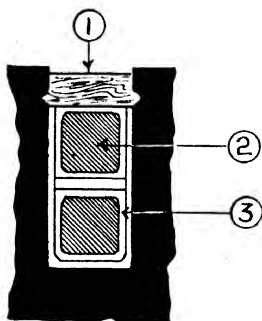
No. 645.—Slot in Armature with
Conductor in Position.

1, Wooden key or locking piece.
2, Copper conductor.
3 Insulation of conductor.
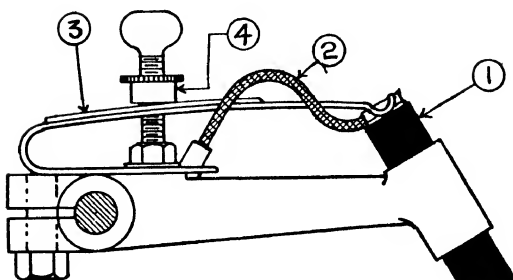
No. 646.—Box Type Brush Holder (Carbon Brushes)

1, Carbon brush
2, Conductor connection to brush.
3, Spring for pressure of brush.
4, Screw for spring adjustment.

No. 648.—Armature Conductor.

End A connects metallically to a copper block of the commutator, and, after looping round the other end B, connects to the adjacent copper block.

No. 647.—Field Magnets of 4-Pole Generator.

1, Magnet core of steel or of wrought iron.
2, Series wound coils of coarse wire.
3, Shunt   ,,   ,,   fine wire.
4, Commutator poles, which correct the field distortion produced by the armature magnetism, and thus admit of the brush position being kept to a fixed mark for all conditions of load. When commutator poles are omitted the brushes require to be advanced when the load is increased to obtain the sparkless position.

No. 649.—Lap Winding.

Observe that the conductor starts at A end on block 1, and after looping round finishes on block 2 at B end.

The loop is arranged to intensify the electrical effect produced in the coil.
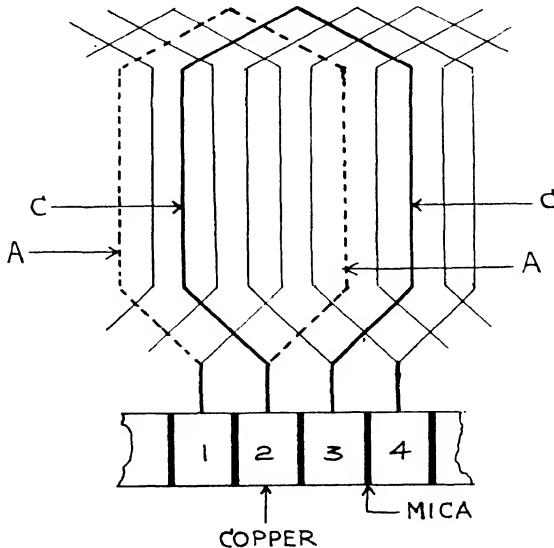
No. 650.—Example of Lap Winding of Armatures.

Conductor A begins on commutator bar 1 and finishes on 2.

,,   C   ,,   ,,   ,,   2   ,,   ,,   3.

That is, each conductor is led off from one bar and completes its path on the adjoining bar, after first passing from front to back of the armature, across the back, then back to the front again.
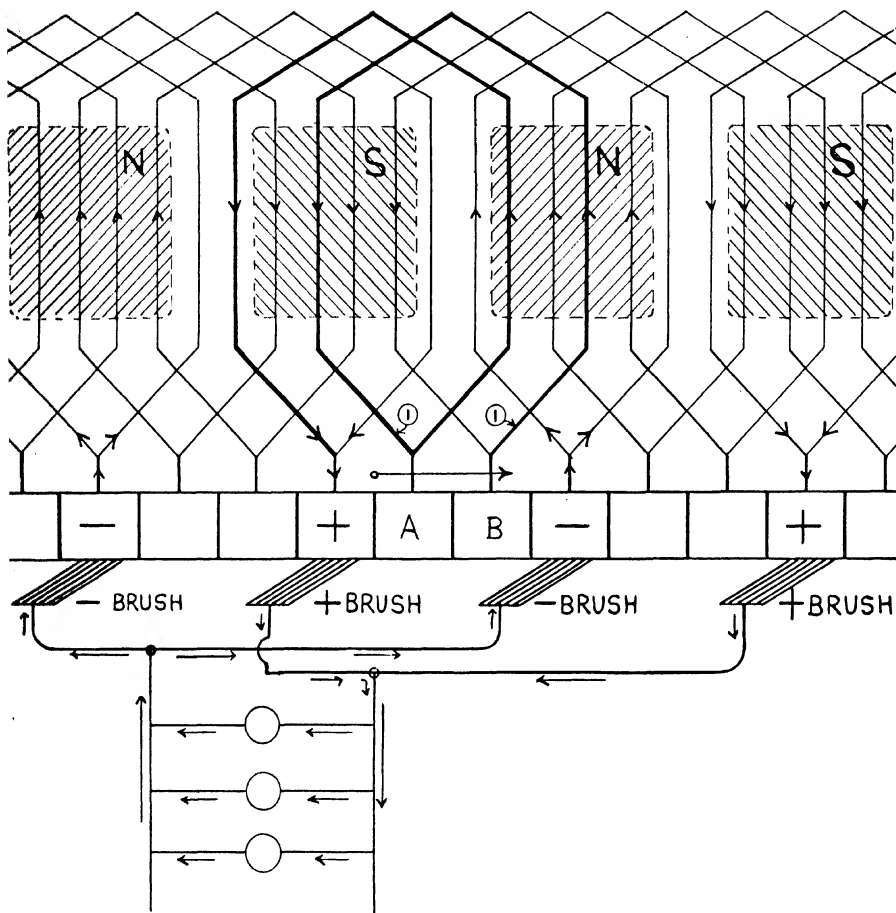
No. 651.—Diagram of 4-Pole D.C. Armature Lap Winding.

Note.—By D.C. is meant " direct current," and A.C. " alternating current."

The above sketch shows an expanded view of the armature windings, magnet poles, commutator, and brushes ; the lamp circuits are also indicated, and the current flow (or E.M.F. induced) represented by the direction of the arrows. Observe that the conductor ① starts on commutator block A, and finishes on block B ; each conductor is coupled up similarly, and by suitably arranging the conductor groupings the combined flow of the current from each conductor *enters* at those blocks of the commutator where the positive brushes are placed (marked +). In the same way at other two neutral positions the current from each conductor flows *away* from the commutator blocks, and these are the positions for the negative brushes.
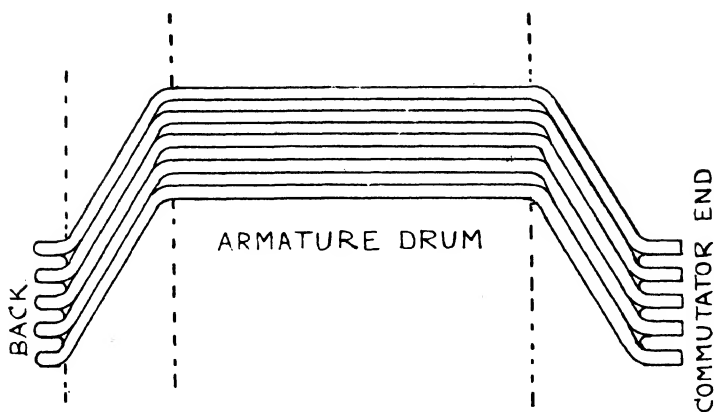
No. 652.—Lap Wound Armature Winding.
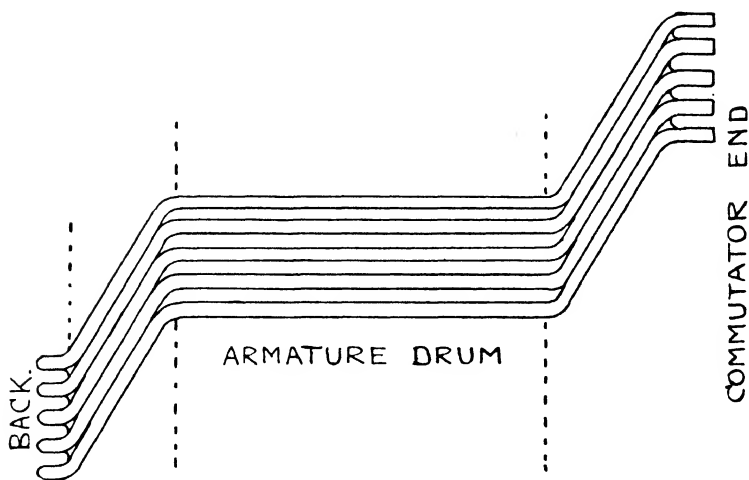
No 653.—Wave Wound Armature Winding.

Observe the difference in the two methods of winding as seen on the drum surface, the lap method forming equal and opposite angles of connection back and front, whereas the wave winding runs off at the same angle back and front, owing to the fact that the conductors connect to different commutator bars than those of the lap winding.
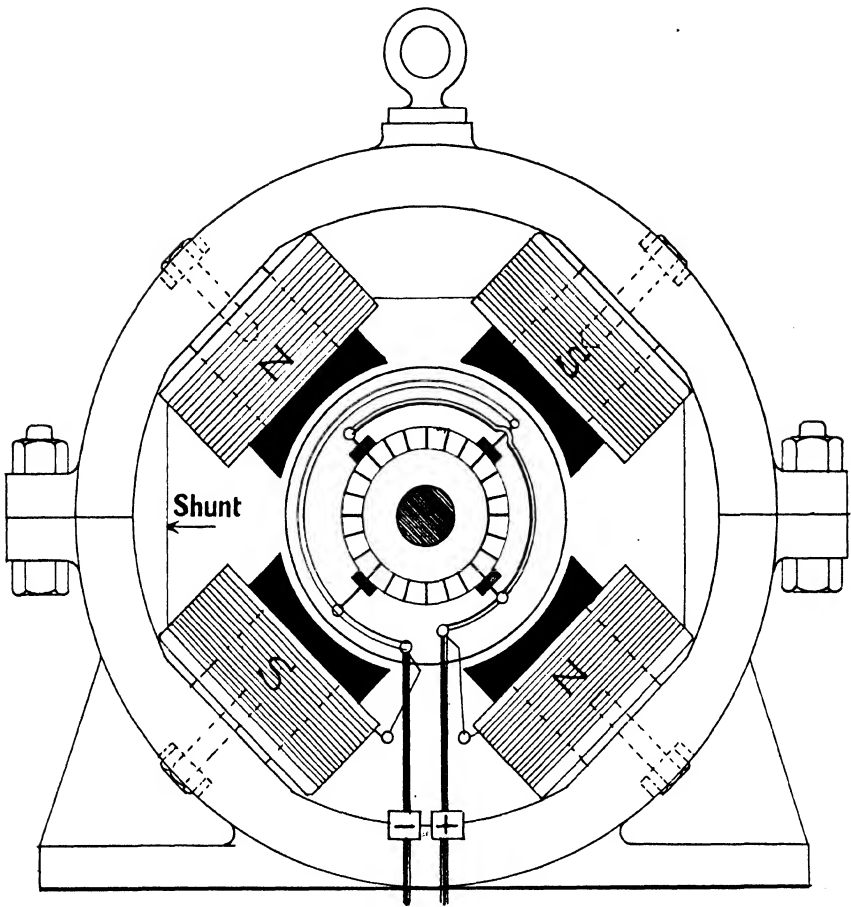
No. 655.—End View of 4-Pole Shunt Wound D.C. Dynamo.

With the armature turning clockwise the brushes opposite the S. poles are positive, and those opposite the N. poles are negative. The two positive sets are coupled together by the ring shown, and the two negative sets are arranged similarly.

The objection to this type of dynamo for parallel lighting purposes is that when lamps are switched off the remaining lights would burn brighter unless the armature speed was reduced to correspond : the reverse also holds good if lamps are switched into circuit, the reason being that the current has two paths open to it, and if the resistance in one of two is increased the other will receive an increase of current, assuming that the armature speed were to remain constant.
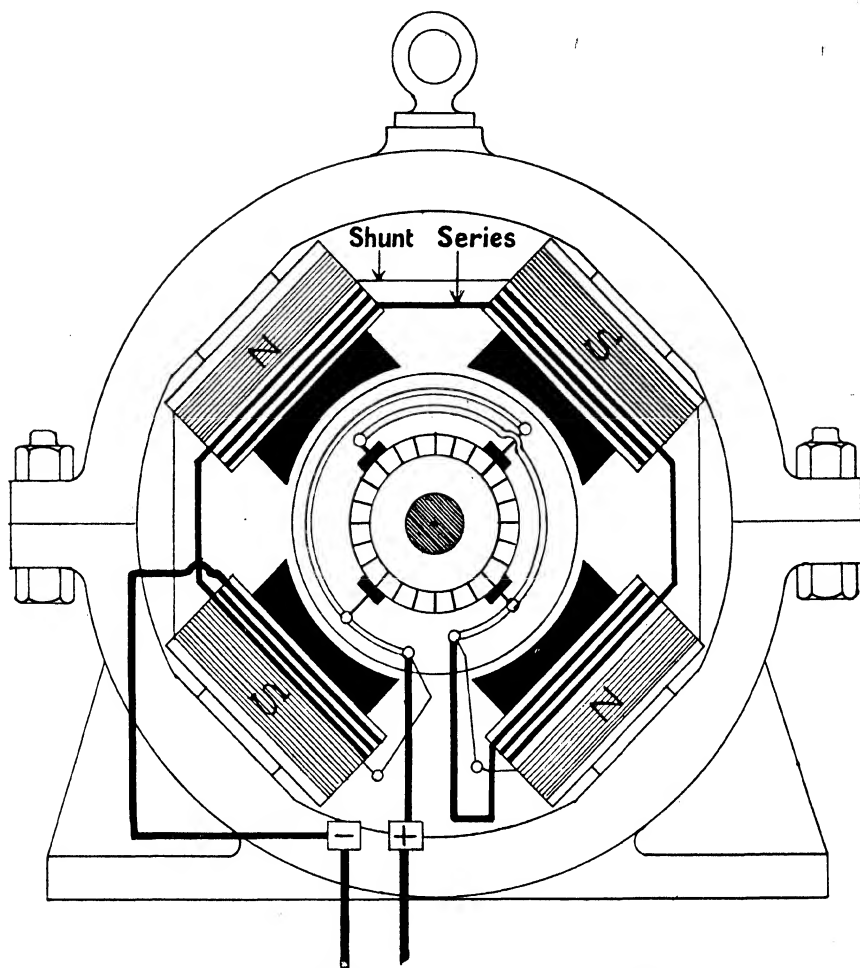
No. 656.—End View of 4-Pole Compound Wound D.C. Dynamo.

With the armature revolving clockwise, the two brushes opposite the S. poles are positive, and it should be noted that they are connected together by a ring-piece to which is fixed the positive series winding wire.

The negative brushes are opposite the N. poles, and the two sets of brushes are also connected to each other and to the negative series winding wire.

Observe that the shunt winding starts from one brush connection, is led round the four magnet poles, and returns to the other brush connection, thus completing its path. Again it should be noted that only a few series turns are employed, whereas a great number of the fine shunt windings are necessary.

Motor Starting Resistance, etc.

The reader is advised to carefully study the following extract from an article entitled "Some Notes on Elementary Electrical Engineering," by W. Benison Hird, B.A., M.I.E.E., dealing with the principle of motor starting switch resistances, which is of particular value to the marine engineer officer.

"In these notes an attempt is made to put the reader in the way of solving for himself such of these questions as relate to elementary electricity and magnetism and the simpler facts concerning dynamos and motors.

"There are two elementary laws or principles which, properly understood and applied, will carry him very far towards the solution of many at first sight puzzling facts in elementary electrical engineering.

"First.   The current flowing in any circuit is equal to the sum of the electromotive forces in that circuit divided by the resistance.

"That is to say, that a given E.M.F. being applied to the terminals of any circuit, a perfectly definite current will flow through it, and that current will be proportional to the E.M.F. divided by the resistance. If the E.M.F. is measured in volts and the resistance in ohms, the ratio $\dfrac{\text{E.M.F.}}{\text{Resistance}}$ will represent the current in amperes In symbols, if E represent the E.M.F. in volts, R the resistance in ohms, and C the current in amperes, then $C = \dfrac{E}{R}$.

"Second.   The second principle to remember is the observed fact that if any conductor is moved in a magnetic field so as to cut the lines of magnetic force, an E.M.F. will be generated in the conductor.

"A magnetic field is any portion of space under the influence of a magnet. Every magnet has two poles, a north pole and a south pole, and we can imagine the whole of the space near the magnet as filled with imaginary lines running from the north pole to the south pole, and along which the force of attraction of the magnet acts. Such lines are known as lines of magnetic force, and the number of such lines in a given area depends upon the strength of the magnet and the distance they have to pass in getting from the north pole to the south pole ; in fact, it is proportional to the strength of the magnetic field.

"To take a concrete example, take a two-pole dynamo or motor : the magnet consists of a horse-shoe shaped piece of cast steel, and is converted by the current circulating in the field coils into an electro-magnet with a north pole at one end and a south pole at the other ; when the armature is put into this magnet a narrow air gap is left between the steel of the magnet and the iron of the armature core ;

this narrow gap must be imagined as filled by a large number of lines of magnetic force running from the north pole of the magnet into the armature iron and out of this into the south pole of the magnet. For the most part these lines will run radially and straight across the gap, but at the edges of the magnet they will spread out and form a fringe extending into the armature iron at some little distance from the magnets. Forming a mental picture of such a magnetic field, it is evident that any conductors laid on the armature parallel to the shaft will, when the armature rotates, cut the lines of force, and will therefore have an E.M.F. generated on them.

" Note that it is only an E.M.F. that is generated, and that there is not necessarily any current flowing in the conductors. In order that current may flow, another condition is necessary besides the cutting of lines of force, and that is that the conductors should form part of a closed circuit to carry this current, and if such is the case the current will then follow our first law, and the amount of current flowing will be equal to the E.M.F. generated divided by the total resistance of the circuit.

" Further, a conductor placed in a magnetic field and carrying a current will tend to move in such a way as to cut the lines of magnetic force, the direction of motion being such as to generate an E.M.F. opposing the current.

" In illustration of the above apply these principles to some of the simplest and most elementary questions which are likely to occur to anyone just coming into contact with dynamos and motors.

" The resistance of a motor armature is necessarily very small : high resistance in the armature winding would mean large losses, which would be injurious in two ways. First, as all losses appear ultimately as heat, they would cause too high a temperature rise to the detriment of the insulating materials, which would rapidly perish ; secondly, they would mean an unnecessarily low efficiency, for evidently these losses must be supplied from some source, and must mean that an increased power is taken from the mains to give out the same power at the pulley. This being the case, the armature resistance is kept as low as possible, and if the motor were put directly on to the mains, it would momentarily take a very large current. Take a numerical example. A 10 H.P. motor designed to run at 500 volts will have an armature resistance of about ·5 ohm. If such an armature were switched directly on to the mains at 500 volts, it is readily seen from our first principle that the current would amount to $\frac{500}{\cdot 5} = 1000$ amperes, but the normal current of the motor when giving 10 H.P. is only about 20 amperes ; the mains and armature conductors are only designed to carry 20 amperes, and such a large current as 1000, even if only for a moment, is very

excessive, and evidently out of the question. Even apart from any *electrical consideration, the mechanical effect* of such an excessive current would be damaging in the extreme to the mechanical parts of the motor and of the machines it might be driving ; to put suddenly on to any machine a force fifty times in excess of what it is intended to carry is evidently courting disaster. For this reason a resistance is inserted to check the momentary flow of current. Say a resistance of 19·5 ohms is inserted in circuit with the motor, then the current flowing through the circuit will be $\frac{500}{20} = 25$ amperes. The armature conductors are now in a magnetic field, and they are carrying a current of 25 amperes. They will tend to move in such a way as to cut the lines of magnetic force, and the armature will start to rotate. As soon as rotation begins an E.M.F. will be generated in the armature opposing the E.M.F. applied to the terminals, and this back E.M.F. will increase as the speed increases, because the E.M.F. generated by the cutting of lines is proportioned to the rate of cutting. After the armature has attained a certain speed, the back E.M.F. will be, say, 200 volts. Then the effective electromotive force in the circuit will be 500 – 200 volts = 300 volts, 500 volts at the mains and an E.M.F. of 200 volts generated in the motor armature, and acting in the opposite direction. Again, divide E.M.F. by resistance, and we will find that the current will now be $\frac{300}{20} = 15$ amperes. Will the armature increase in speed and the current be further cut down ? This depends entirely on what work the motor is put to. Say it is driving shafting ; if 15 amperes is just sufficient to drive the shaft, the speed will not increase, and the motor will go on running steadily at the same speed. If, however, a smaller power is sufficient to drive the shaft at this speed, the motor armature will go on accelerating, the E.M.F. generated will also increase, and further reduction of the current will take place. Assume that 15 amperes is just sufficient to drive the shaft, the motor will then continue running at the speed it has now reached. Now is the time to cut out some of the resistance introduced in the circuit. Say this is reduced by moving the starting switch on to the next contact to 11·5 ohms, the fotal resistance in circuit will be 12 ohms, and we have seen the effective E.M.F. to be 300 volts ; the current will therefore rise to $\frac{300}{12} = 25$ amperes. This is more than what is required to keep the shafting in motion, and the armature will therefore increase in speed : the back electromotive force will also increase and the current be cut down in value until it again reaches the value of 15 amperes. The process is then repeated until all the resistance is cut out and the motor is running at normal speed.

Reasons for Increase in Motor Speed after Inserting a Resistance.

To many beginners in the subject it appears that one would more naturally expect the reverse to be the case, and that putting in resistance would lower the speed, and taking it out would increase the speed. On consideration, it is easily seen that this view is erroneous. The shunt circuit of a motor is a separate circuit, having a definite resistance and connected across the mains, so that it has a definite E.M.F. on its terminals ; it will therefore carry a definite current $C = \dfrac{E}{R}$, where C is the shunt current, R the resistance of the shunt circuit, and E the E.M.F. at the mains. Now, any increase in the resistance evidently decreases the current and weakens the magnetic field. There will be fewer lines of magnetic force flowing across the air gap of the motor, but in order to give the same back E.M.F. the conductors must cut the lines of force at the same rate. Since there are fewer lines to cut, the conductors must cut what there are quicker, that is, the armature will speed up. Why must the armature keep up the same back E.M.F. ? Because if it does not, the effective E.M.F. in the circuit is greater ; the current being equal to the effective E.M.F. divided by the resistance of the armature circuit is also increased, and the armature taking a current greater than that required to overcome the load will accelerate.

Testing for Faults.

Testing can be done by means of a " detector " formed of a magnetic needle and galvanic battery, or by a small portable hand
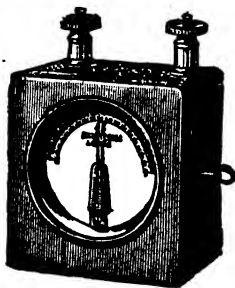
No. 657.—Detector.

lamp with a length of wire connected to each of its terminals. When using the hand lamp the ends of the copper wires must be carefully stripped of insulation so that the copper is bared.

The detector can be used in most cases when the dynamo is stopped, but the lamp can only be used when the dynamo is running.

The detector is supplied with a battery, so that a current will flow through it and deflect the needle whenever the positive and negative poles of the dynamo or wires to be tested are connected up to the terminals of the detector.

In the case of the portable lamp, a current must first be sent through the wires, etc., when the ends of the lamp wires are put in contact with the positive and negative connections under test, before the light will show in the lamp.

NOTE.—A " short circuit " is a connection (usually metallic) between any positive and negative part of the dynamo connections, or between any two of the wires. An " earth " is a metallic connection between one of the poles of the dynamo or wires to the metal of the ship's plates.

Break in Main Wires.

To discover the position of a break in a pair of wires, begin from the source of the current in question or distribution box from which the wires branch off, and baring the two wires at short
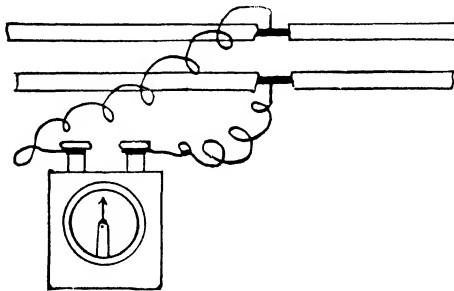
No. 658.—Broken Wire Test by Detector.

distances, touch them both with the free ends of the wires connected to the detector. If the needle deflects, a current is passing at the point tested ; but if after repeating this a few times the needle does not deflect at a point further on, it indicates that a break is situated somewhere between this point and the last place where the needle deflected.

The wires will therefore require to be carefully examined between the two places referred to for the location of the break.

The portable lamp will do equally well as the detector, only in

this case the dynamo must be run to obtain a light in the lamp when the bared ends of the lamp wires are put in contact with the wires
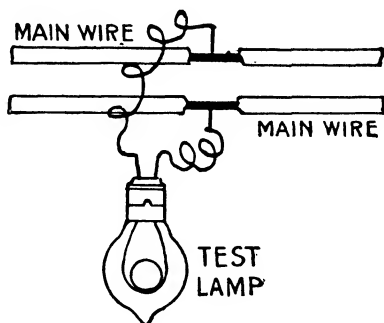
No. 659.—Broken Wire Test by Lamp.

under test. If at a certain point no light shows in the lamp, it indicates a break in the current or circuit.

NOTE.—The switches of the circuit in question must be " on " when testing with the detector.

Leak in Magnet Coils.

To test if leakage is occurring between the magnet coils and magnet, connect one of the detector wires to the end of the coil
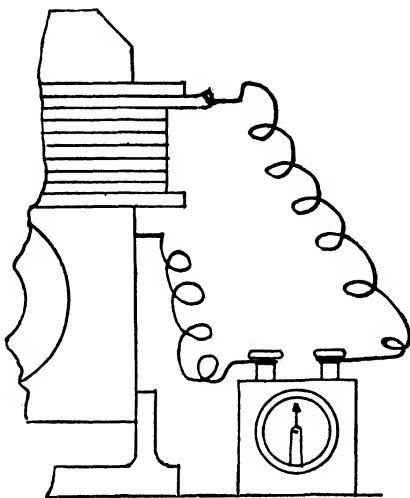
No. 660.—Test for Leakage between Coils and Magnet.

to be tested, and after carefully cleaning and polishing up a small part of the metal work of the magnet, put the end of the other detector wire in close contact with it. If the needle deflects, it indicates a leak between that particular coil and the core of the magnet: if no deflection of the needle takes place, it proves the insulation to be intact. Each coil will require to be tested in turn.

Leak between Armature Coils and Armature Drum, or between Commutator and Armature Drum.

Take out the armature and support it on a pair of trestles, place one detector wire on the armature shaft or drum (either will·
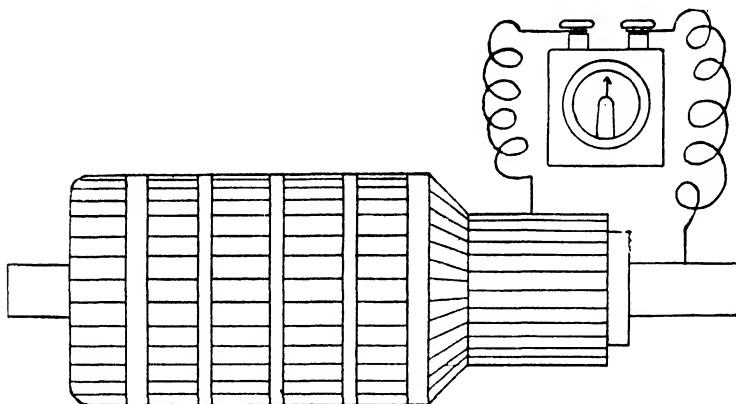
No. 661.—Test for Leakage between Armature Coils and Drum.

do) and with the other wire touch the commutator bars as the armature is slowly turned round. If the needle deflects it indicates a short circuit between the armature coils or commutator bars and the drum.

Short Circuit in Brush-holders.

Lift the brushes from the commutator and disconnect them from the cables leading to the dynamo terminals, then place one detector wire on one brush-holder, and the other detector wire on the other brush-holder. If the needle deflects, a current is passing

indicating a short circuit. Each part of the brush connections can be tested in the same manner.
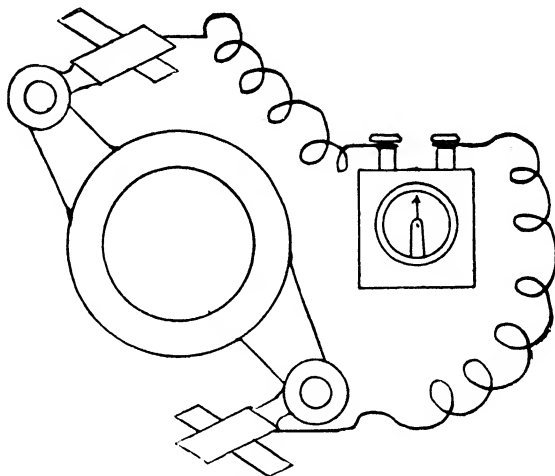
No. 662.—Test for Short Circuit between Brush-holders.

Test for Broken Wire.

Disconnect the wire to be tested so that the ends are free, and place one detector wire to each end.   If the needle deflects, a current
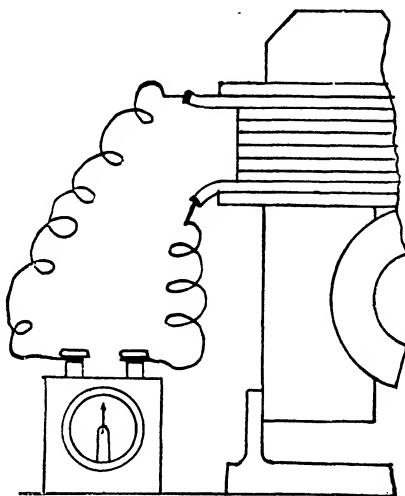
No. 663.—Test for Broken Wire (Continuity Test).

is passing, and the wire is not broken ; but if the detector needle remains stationary, it indicates that the wire in question is broken, as the circuit is not complete.

Test for " Earth " Leakage.

With the main and lamp switches " on," connect one detector wire to the positive and negative wire of the dynamo in turn, and put the other detector wire in contact with the floor plates or ship's skin as the case may be. If a deflection of the needle occurs, it indicates that leakage to " earth " is taking place, that is, at some part of the circuit one of the wires is in bare contact with the metal
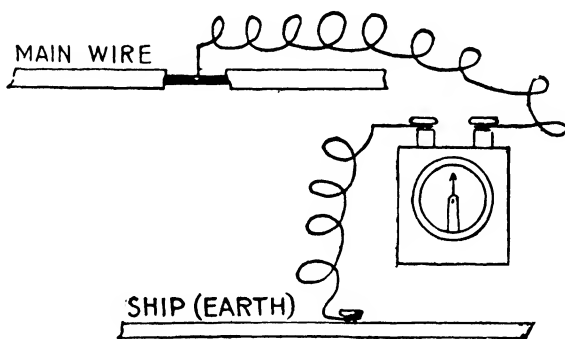
No. 664.—Test for " Earth " Leakage.

of the ship, and the current is returning to the dynamo by that path.

To locate the part of the circuit affected, switch off the main switches one by one till the needle comes back to its zero position, and the last switch opened will be that of the circuit affected. Now connect one of the detector wires to one of the " bus " bars or terminals of the distribution box of the circuit, and, as before, connect the other detector wire to the ship's metal. If the positive and negative fuse bridges in the box are now pulled out one by one, the needle will only move back to zero when the fuse bridge of the " earthed " wire is disconnected, and in this way the exact " earthed " wire can be located.

Another method of carrying out this test, should a galvanometer not be available, is to connect up a lamp, the lamp being of the same voltage as the dynamo. In this case it is necessary to have the

dynamo running and to test both negative and positive sides of the leads, as the lamp only lights up when there is a fault on the opposite pole to that to which it is connected. For instance, should there be a fault on the positive lead to a lamp, when the test lamp is connected to the negative wire it will light up, but if connected to the positive it would remain black.

" Earth " Lamp Test.

To test for an earth leakage arrange a pair of lamps as shown in the sketch, one connected to the positive lead, the other to the negative lead, and both connected to the ship metal by a cross wire.
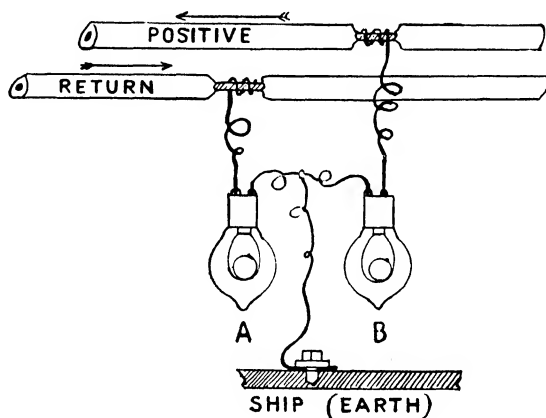
No. 665.—Earth Lamp Test.

With the dynamo running, one of the lamps will burn brighter than the other if there is a leakage to earth, and the leak will be on the opposite wire to that of the bright lamp. For example, if lamp A burns brightest the leakage will be on the positive wire, but if lamp B burns brightest then the fault is on the negative or return wire. See also p. 982.

To Test for Short Circuit in Main Wires.

Disconnect one of the main wires from the dynamo terminal, and insert between the wire and terminal the detector, as shown. Now switch off the lamps (not the main switches), and run the dynamo. If a deflection of the needle takes place it indicates a short

circuit between the main wires, as with the lamp switched off no current should then be passing.
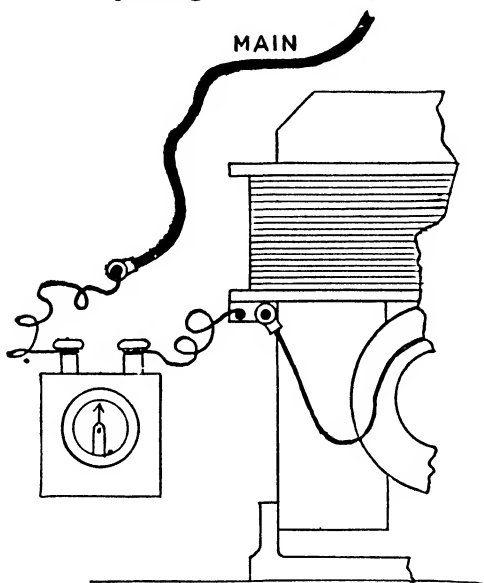
No. 666.—Short Circuit Test.

To Test for Broken Armature Coil.

This can only be accurately determined by the following method :—Disconnect both ends of each armature conductor from

END OF COIL

END OF COIL
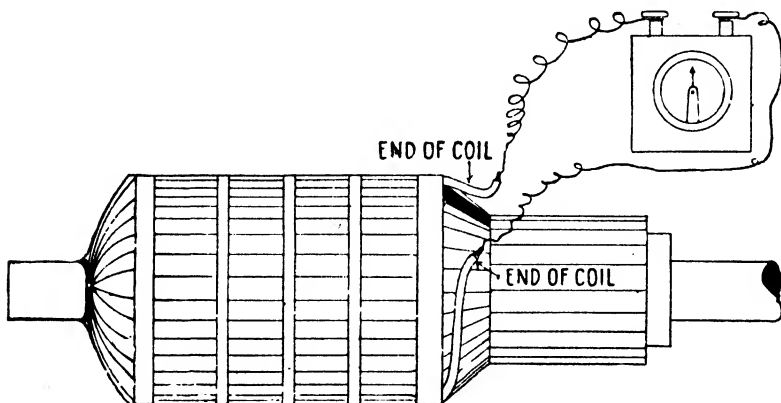
No. 667.—Test for Broken Armature Coil.

the commutator bars, and place one wire of the detector to each end; then if no deflection of the needle takes place it indicates a broken wire: a deflection proves the wire to be continuous or unbroken. Each armature coil must be tested separately.

To Test for Polarity of Dynamo.

It is often very convenient to know which is the positive and which the negative connections or wires of a dynamo, and these can be located as follows :—
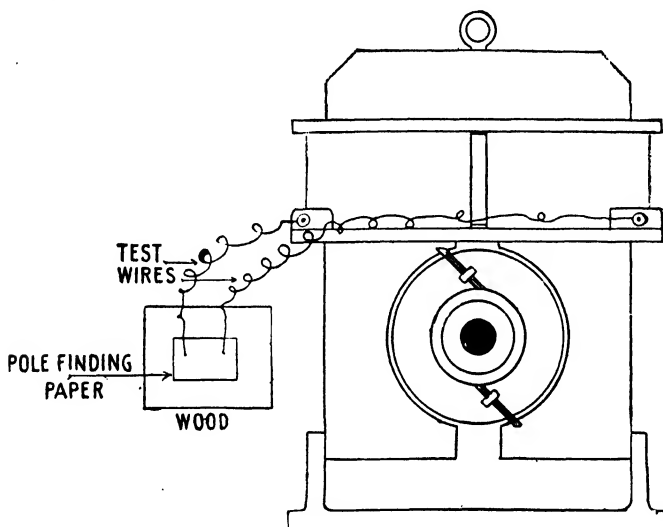
No. 668.—Polarity Test.

Obtain a piece of " pole-finding " paper (procurable at any Electrical Supply Stores), and after moistening the paper place it on a piece of dry wood ; now lead a suitable length of wire from each dynamo terminal, as shown in the sketch, and with the free ends of the wires touch the wetted " pole-finding " paper. A red coloured blot will then appear on the paper at the wire connected to the *negative* terminal ; the other will of course be the positive connection.

Hints on Running.

In the case of a new dynamo it is advisable to run the machine for a couple of hours or so with the brushes lifted from the commutator, as a test of the mechanical balance, lubrication, etc.

The armature, commutator, and field magnets should be kept absolutely free of dust, grit, oil, or moisture, as these allow of the formation of short circuits.

The commutator should be supplied with the *least amount* of lubrication possible, and that only of vaseline or mineral oil.

A commutator in good working condition presents a surface covered with an even bronze glaze or skin, and this should be maintained if at all possible.

The brushes should be placed at *exactly* opposite positions on the commutator circle (mathematically opposite).

It is safest to first get the speed up on the dynamo, and the proper voltage showing on the voltmeter, before switching in the lights.

Examine the armature conductors to see that the commutator ends of the wires are not bent and in contact with each other, as this will produce a short circuit.

Keep all small tools away from the dynamo, as the magnetic attraction may draw them into the field space and result in serious damage.

Brass or copper oil cans only should be used.

To test the armature balance, lift it out and place the shaft on two fine levelled knife edges ; if the armature is then gently rolled from side to side it will come to rest with the heavy side down ; this side should therefore be reduced in weight, or the other side increased in weight.

Short circuits in the armature coils show either by burning of the insulating material resulting in a strong smell, or merely by heating up of certain coils when felt by hand immediately after stopping the dynamo.

If a commutator develops an untrue surface or " flats," it should be turned up with a diamond-nosed tool, as this type of tool prevents the burring of the copper edges over the insulation.

Make sure that the binding terminals are screwed up and in metallic contact.

If the dynamo has become demagnetised it will refuse to generate current when the speed is up. To remedy this, either tap the field magnets with a light hammer, or, if this fails, reverse the brushes, that is, turn them round 180 degrees of the commutator circle (if a two-pole machine), so that they change places with each other, and run the machine for a short period with reversed current ; this tends to restore the magnetic conditions : afterwards replace the brushes to their original positions. See also p. 980.

Excessive rise of temperature in fields or armature indicates a short circuit between some of the wires.

A short circuit or earth leak may result in overloading the dynamo and produce sparking at the brushes.

In place of the ordinary galvanometer or detector a small bell and dry battery may be used for testing. When the circuit is completed by the wires from the bell terminals the bell will ring.

Whenever possible slow down and stop the dynamo before switching off the lights, as this prolongs the life of the incandescent lamps.

Before starting up the dynamo be sure that the lubrication is reliable and the oil cups filled up ; also that the armature shaft is clear.

The brushes should not be lifted from the commutator while the dynamo is running, as this produces destructive sparking.

Sand-paper only should be used to polish up the commutator surface, and it should be applied by means of a board on which the sand-paper is pasted, the width of the board to be cut to the length of the commutator bars.

Hold the sand-paper board against the commutator, and have the armature shaft revolved by hand. This is best done with the armature lifted out and laid on a pair of wood trestles.

At intervals feel by hand the temperature of the magnet coils.

It is important to see that the engine is not started to run in the wrong direction, that is, against the brushes, as damage would result.

The brush position, when the machine is running without load, will not be suitable when the load is on, and the brushes must then be rocked forward to obtain a sparkless contact.

NOTE.—" Forward " means in the direction of rotation.

In polishing up the commutator in position, take care to lift up the brushes clear of the commutator surface.

The voltage of the dynamo varies in proportion to the speed of the machine.

If a fuse blows or burns out it should be replaced by one of the same size, and not by a larger one as is sometimes done.

Violent sparking at the commutator may be caused by a broken armature coil, or broken armature and commutator connection.

The " pilot " lamp serves as a guide to the voltage of the dynamo, as, being connected direct to the dynamo terminals, it indicates whether the machine is generating the required E.M.F. or not. If therefore a fault appears on a section of the lighting circuit and the pilot lamp of the dynamo is still burning brightly, it proves that the fault is not in the machine, but must be in the wiring or lamps. If the speed is too high this may show in the pilot lamp by possible burning out, and if too low, by the lamp only glowing instead of being at a white heat.

Engine-room " waste " should never be used on a dynamo, as the loose fibres are apt to detach and lodge between the commutator bars

or armature coils, and ultimately bring about short circuits. A linen cloth is much to be preferred.

Become acquainted with the usual temperatures of the machine at different parts when running, so that any abnormal rise of temperature may be noticed at once, and the cause located.

When lifted out of the bearings the armature should be laid on a pair of wood trestles as mentioned elsewhere, or if laid on the floor
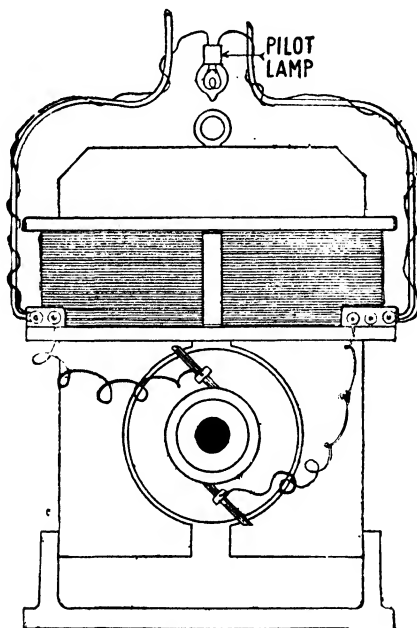
No. 669.—Pilot Lamp.

should rest on sacking or some such soft material, as, being a delicate piece of work, it easily becomes damaged.

By careful adjustment of the brush rocker the best position of the brushes can be found, and this should give a practically sparkless contact.

See that the brushes have no side-play in the holders.

The point or toe of copper gauze brushes should be cut to an angle of about 40°.

Apply the necessary lubrication to the commutator either by the palm of the hand or by means of a piece of *linen* rag, and remember that a very small amount of mineral oil is sufficient.

If the armature is much out of balance it will probably injure both the commutator and the brushes.

The disadvantage of carbon brushes is a tendency to heat up if

not accurately adjusted, as, for example, by excessive compression on the holder springs.

If the dynamo is situated in a part of the steamer where the temperature is high (say 100°), sparking will ensue at the brushes and commutator, owing to the increased resistance due to heating.

If the dynamo is placed near the condenser, corrosion of the tubes may result, due, it may be supposed, to galvanic action. This has occurred in several cases which have come under the writer's observation.

When the carbon brushes become rough at the bearing edges, they can be quickly repaired by re-bedding accurately on the commutator surface.

NOTES ON ELECTRIC STEERING GEAR

Where electric power only is to be used for steering, one of the following systems is usually employed :—

Motor-Generator or "Ward-Leonard" System.

This system has been developed by Messrs Laurence Scott & Co. Ltd. It has proved in service one of the most reliable and efficient type of steering gear at present in use.

The rudder motor (geared to the steering quadrant) is not supplied direct from the ship's mains, but from a special electric generating plant. This consists generally of a motor generator in the steering flat. The motor end of this is running continuously off the ship's mains and driving the generator end, which can supply any voltage (from o to full in either direction) to the rudder motor.

The electric connections between the generator and the rudder motor are permanently made without switches, and the motor starts, stops, or reverses according to the supply from the generator.

The voltage of the generator is determined by the direction and strength of the small current flowing in its shunt (or fine wire), exciting coils on the field magnets, and this is determined by the motion of the wheel in the following manner :—

There are two similar " rheostats " (or adjustable resistances), each with a screwed shaft. One of these is connected to the wheel and the other by gearing to the rudder motor. There is a nut on each shaft carrying a sliding contact along a scale marked off in degrees.

The two "rheostats" are connected up electrically in what is known in the text-books as a "Wheatstone Bridge" circuit, the exciting circuit of the generator occupying the position of the galvanometer in the text-book diagram. A small current flows continuously through the rheostats, but as long as the two sliders correspond in position no current flows between them. If the wheel is moved and displaces its slider one way or the other, the current flows in one or other direction between this and the slider in the steering flat.

No. 670.—Electric Steering Gear.

(Ward-Leonard System.)

1, Ship's mains.
2, Motor for driving generator (8) (shunt wound).
3, Steering wheel rheostat.
4, Rudder rheostat.
5, 6, Exciting current wires from rheostat.
7, Exciter for generator (separately excited).
8, Generator.
9, Rudder (main) motor, compound wound and separately excited from ship's mains.

10, Pinion drive to rudder quadrant.
11, Slider nut on rudder rheostat which operates as a hunting gear.
12, Slider nut on steering wheel.
13, Limit switch stop.
14, Current from ship's mains to rudder motor field and which always flows in one direction only.
15, Magnetic brake.

972

The " Ward-Leonard " system of all electric steering gear includes the following units :—

1. A motor supplied by current from the ship's mains.
2. A generator direct coupled to the motor, and which runs continuously in one direction only.
3. An exciter in one with the generator and which generates field strength only when supplied by the rheostat position of the steering wheel : the generator is thus separately excited.
4. A steering motor direct coupled to the rudder pinion wheel or quadrant and the field of which is supplied by current from the ship's mains which flows in one direction only at all times of action.
5. A magnetic brake which functions to hold the rudder in any position of helm when the rudder motor stops running.

If steering wheel is turned so that the slider (12) comes into position A, the arrows marked A, A show the effect produced when the electrical balance is upset, the current flowing from the positive main into the exciter (7) of the generator (8) and back again to the negative main. B shows the effect produced when the electrical balance is upset on the other side of the rheostat, and how the current flows (B) from the positive main through the exciter coils and back again to the negative main. When the steering wheel slider (12) is moved into, say, position B, the rudder motor in revolving operates the slider (11) to work back to the corresponding position (two contacts from the end) on the rudder rheostat, with the result that the electrical balance is again restored, and current ceases to flow through the coils of the exciter; the rudder motor, therefore, comes to rest, and a magnetic brake (15) is fitted to hold the rudder in position when the motor has stopped running.

The field magnet coils of the generator are not connected to the brushes, and the generator can only be magnetised by current supplied externally from the exciter coils, or what is known as " separately excited."

When, therefore, the steering wheel and the rudder rheostats are in balance, no current is passing into the exciter coils nor generator field, with the result that although the generator armature is being revolved by the driving motor, no current is generated and the main rudder motor, therefore, remains at rest.

If, however, the electrical balance is upset by movement of the steering wheel rheostat, current then enters the exciter coils, which in turn energise the field coils of the generator, and the latter, although revolving at practically the same speed as before, is now passing current from its brushes into the armature of the rudder motor through its brushes.

The latter converts the electrical energy thus generated into mechanical energy to operate the pinion or worm of the rudder quadrant and produce movements of " helm."

Again, it may be noted that the motor and generator revolve constantly in the same direction of rotation, but when the current supply from the exciter to the generator fields is reversed, the direction of rotation of the rudder motor is also reversed, so that port and starboard movements of the rudder can be obtained as required.

When the rudder travels over to port or starboard the limit switch (13) strikes a stop which brings up the motor and prevents over-running of the gear.

Note.—In electric steering gears of the " Donkin " type a worm and pinion gear drive is employed from the motor so that for any position of " helm " the friction of the worm and pinion wheels prevents reversal of motion, if, say, a heavy sea strikes the rudder. In this case double buffer springs are fitted on the rudder quadrant and tiller arm to take up and absorb shock stresses.

It should be noted that the voltage passing to the generator from the rheostat slider varies directly with the number of contactors included in the movement of the slider.

Observe that the steering wheel rheostat slider wire and the rudder rheostat slider wire are connected *through the field of the generator exciter,* hence the reversal of current as required.

Magnet Windings of D.C. Generators and Motors.

For ship-lighting purposes at, say, 110 volts, or 220 volts (which latter E.M.F. is rapidly coming into general practice), compound winding is adopted for reasons explained in other pages of this volume.

For ordinary motor drives, such as, say, for pumps, machines, steering gear, etc., shunt winding is preferred, for the reason that under the usual load fluctuations to be expected, the revolution speed remains practically constant. The motor may, however, momentarily lose speed when the load is increased, or gain speed momentarily when the load is reduced, but the balance is quickly restored and the usual revolutions are maintained as before.

Series-wound motors are only employed for low-power drives, such as for local cabin ventilation fans, or similar purposes.

For a motor subject to sudden and heavy load variation, compound winding is to be preferred.

Compound Wound Generators.
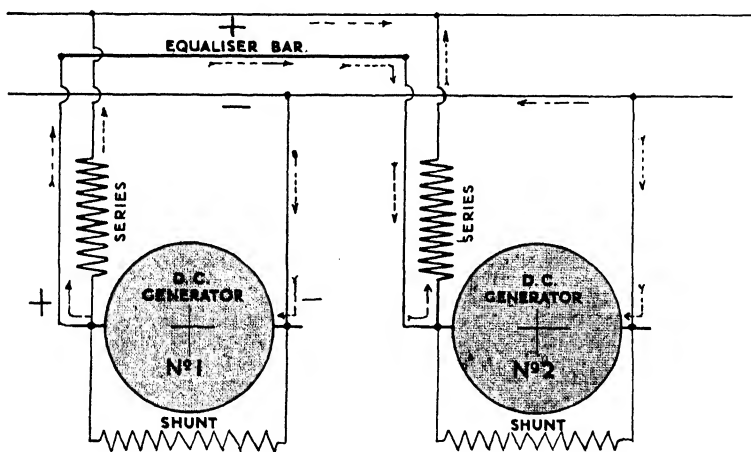
No. 671.—Compound Wound D.C. Generators in Parallel with Equaliser Bar on Switchboard.

The arrows show the current flow which takes place when, say, generator No. 2 falls off in speed and output owing to, say, driving engine trouble.

No. 1 generator supplies current to No. 2 generator field as clearly shown, with the result that both machines operate at equal load.

NOTE.—In switching-on say, No. 2 generator, the equaliser switch must first be closed, followed by the D.P. main switch, and in cutting-out, the main switch should first be opened, followed by the equaliser switch.

The supply to the mains will, of course, be reduced, and the lighting will be affected.

If two or more generators were connected to the same bus bars on the back of the switchboard without an equaliser bar, the sketch No. 672 shows the effects which might occur if, say, the driving engine speed and output of No. 2 generator fell off. In this case current from dynamo No. 1 would flow to dynamo No. 2, and the latter would then function as a motor, and the machine would become depolarised owing to the current flow being reversed, as shown by the arrows.
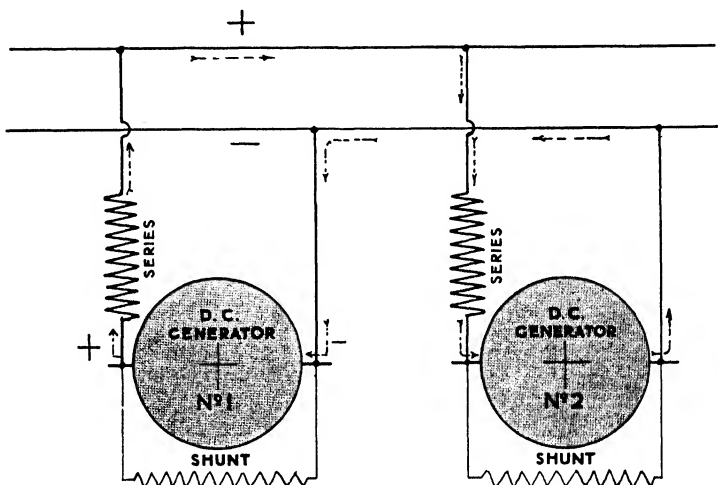
No. 672.—Compound Wound D.C. Generators in Parallel Without an Equaliser Bar on Switchboard.

The result of this reversal would be to put the two generators *in series* with each other, as shown, so that No. 1 machine would tend to overheat and possibly break down through excessive load.

In large tanker practice two generators are often employed without an equaliser bar on the back of the switchboard, but in this case each machine is provided with separate positive and negative bus bars, and operate as two units. If the driving engine of each generator can be relied upon this arrangement gives satisfactory results, and it may be mentioned that circuit breakers are dispensed with, double pole switches only being provided.

If connected to the same bus bars and with no equaliser bar fitted, then reverse current circuit breakers should be fitted to prevent depolarising of the faulty machine.

Megger.

This instrument is employed to measure the resistance of insulation in wiring, generators, motors, etc. The resistance is usually registered in megohms or fractions of megohms.

NOTE.—One megohm = 1000000 Ohms. One microhm = $\dfrac{1}{1000000}$ Ohm. A standard Ohm is equal to the resistance offered to current flow by a thread of mercury 106.3 cm. long and 1 square mm. in cross-sectional area at a temperature of 32° F.

For shipwork the Megger employed operates at 500 volts, which is taken as equal to at least twice the working E.M.F. of the system under test. The handle requires to be turned at the speed marked on the instrument, say, 60 revs. per min., which generates the required E.M.F. If the insulation were perfect and no leakage taking place the needle would register " infinity " on the dial,
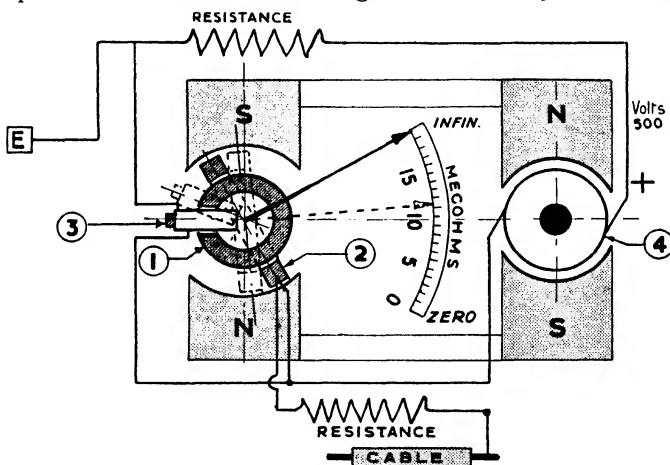
No. 673.—Evershed Megger Testing Set.
(Evershed & Vignoles Ltd.).

The dotted lines show the instrument registering about 12 megohms resistance.
1, Soft iron core pivoted on axis.
2, Current coil connected in series across the generator terminals but also in series with the unknown resistance.
3, Pressure coil connected in series with the generator terminals.
4, Hand operated generator.
E, Earth connection.

but if leakage is taking place current will flow through the current coil and the needle will be deflected clockwise to register the reduced resistance in megohms, etc., one coil pulling against the other.

Each length of wire in a ship installation requires to be tested independently.

In testing for earth leakage, one terminal from the instrument is connected to the wire and the other to earth, say a water pipe or ship's skin, plating, etc.

When testing between two conductors or wires, the terminals are connected to each conductor, the ends of which conductors require to be disconnected meantime.

If the resistance were infinite, then current would only flow through the pressure coil 3 and the pointer would register "infinity." If leakage is taking place, current would then also flow through the current coil 2 with the result that the pull of one coil against the other would produce movement of the pointer in a clockwise direction and register the resistance in "megohms."

Insulation Resistance.

[*The Institution of Electrical Engineers gives the following requirements regarding insulation tests in their publication, "Regulations for the Electrical Equipment of Ships."*]

"The insulation resistance shall be measured by applying a direct current pressure (E.M.F.) not less than twice the working pressure (E.M.F.) between earth and the whole system of conductors and any section thereof with all lamps and fuses in place and all switches closed."

A, The insulation resistance of the lighting circuits so measured shall not be less in megohms than 10 divided by the number of points (lights) on those circuits, except that the insulation resistance of any final lighting sub-circuit need not exceed 1 megohm.

Examples.—Assume that a lighting circuit includes, say, 20 lamps or points.

Then, $\frac{10}{20} = \cdot5$ megohm, or, $\cdot5 \times 1000000 = 500000$ Ohms.

Also assume that another lighting circuit includes, say, 100 lamps or points,

then, $\frac{10}{100} = \cdot1$ megohm, or, $\cdot1 \times 1000000 = 100000$ Ohms.

It should be noted that damp or moisture seriously reduces the resistence of insulation, so that a resistance of, say, 1 megohm registered under damp conditions may rise to 20 megohms or more when tested under dry conditions.

B, "The insulation between the case or framework and every live part of each individual dynamo, motor, heater, arc lamp, or other appliance complete with its switch and control gear, regulating resistance and similar accessories shall not be less than ½ megohm."
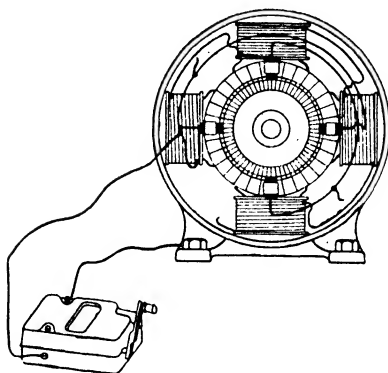
No. 674.*—Megger Test on Motor only, to Frame
or Earth.

In this test the brushes are in contact with the commutator.
If the live parts are properly insulated from the frame (earth) a
high resistance should be registered, if not, an earth leakage exists.

NOTE.—All dynamos and motors require to be efficiently earthed. Copper
plates are sometimes inserted between the bed plate of the machine and the
ship seating to effect this purpose.
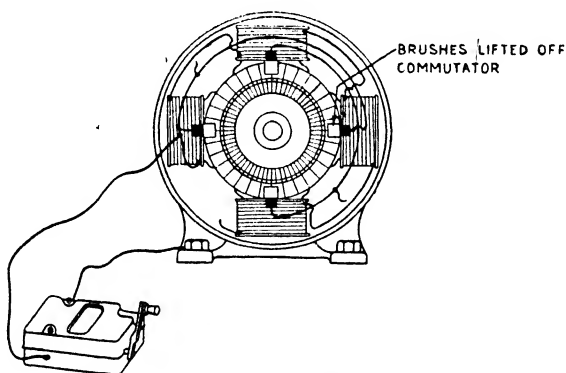
No. 675.*—Megger Test on Motor Field Windings
and Brush Gear only, Armature excluded.

It will be noted that the brushes have been lifted clear of the
commutator. If an earth leakage now exists it is unlikely to be
from the armature.

* Reproduced by courtesy of Messrs Evershed & Vignoles Ltd., " Megger " Manu-
facturers, London.
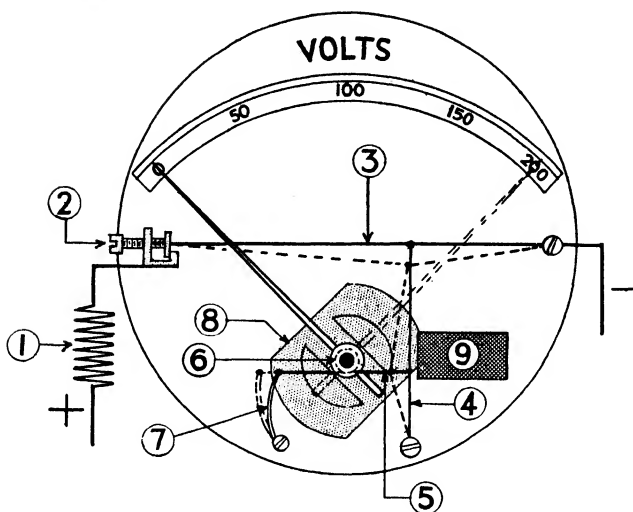
No. 676.—Hot Wire Type Voltmeter.

(For A.C. Current.)

1, Resistance coil.

2, Adjusting screw for tension of wire.

3, Wire of platinum and silver.

4, Phosphor bronze wire.

5, Fine fibre cord.

6, Pulley on dial pointer, round which is wound the fibre cord (5).

7, Flat steel spring.

8, Aluminium disc.

9, Permanent magnet.

The dotted lines show the voltmeter in operation.

Action.

When current passes through the wire (3), heating and expansion take place, with the result that the spring (7) pulls on cord (4) and thus operates the dial pointer clockwise, as shown.

The aluminium disc (8) and permanent magnet (9) are provided to prevent oscillatory movements of the pointer.
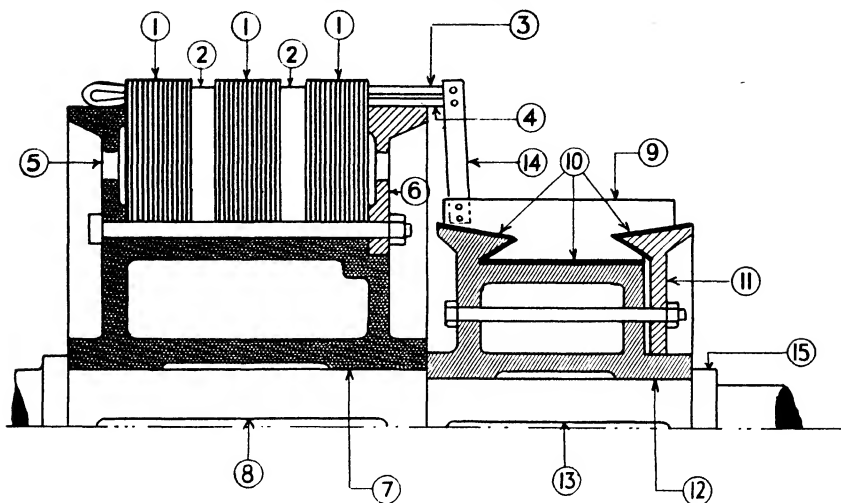
No. 677.—Armature and Commutator Compound Wound D.C. Generator.

1, Soft iron stampings insulated from each other.
2, Ventilation space.
3, Armature conductor (A).
4,   „   „   (B).
5, Ventilation space.
6, Clamping ring.
7, Spider keyed to driving shaft.
8, Key or feather.
9, Copper bar of commutator.
10, Mica insulation.
11, Clamping ring.
12, Spider keyed to driving shaft.
13, Key or feather.
14, "Riser" riveted and soldered to copper bar of commutator and to ends of conductors A and B.
15, Screwed locking ring.

Dynamo Demagnetised.

If one dynamo in a group becomes demagnetised, or depolarised, the magnetism may, in most cases, be restored by carrying out the following procedure:—

1. Open main switch of defective dynamo and stop machine.
2. Lift the brushes from commutator and close main switch.
3. Start machine and run slowly on the shunt for a few minutes.
4. Open switch, stop machine, and replace brushes.
5. On starting up again in the usual way the machine should be restored to normal magnetism.
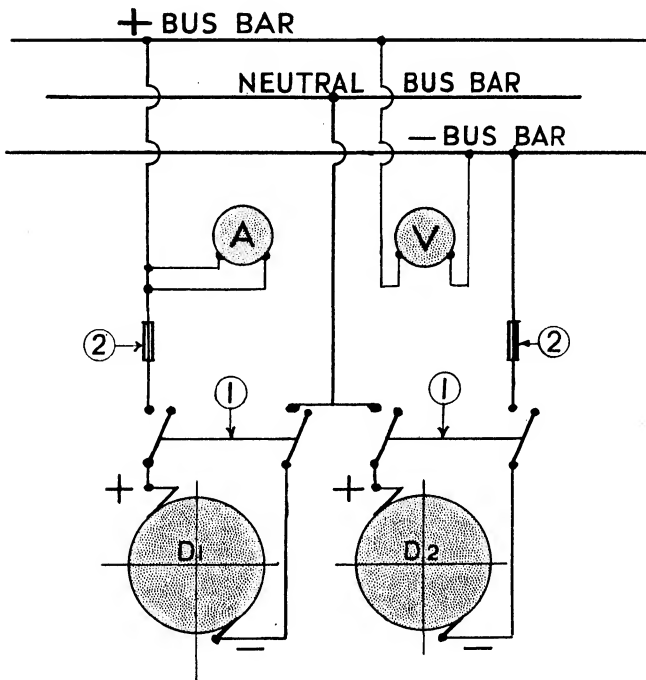
No. 678.—Two Dynamos in Series.

(Three-Wire System.)

A, Amperemeter.

V, Voltmeter.

D_1, Dynamo No. 1.

D_2, Dynamo No. 2.

1, 1, Double pole switches (in "open" position).

2, Fuses.

If one machine gives out the other can be run singly, but the output will be limited owing to the smaller sectional area of the neutral wire which is designed to carry the out of balance current only. See also p. 984.
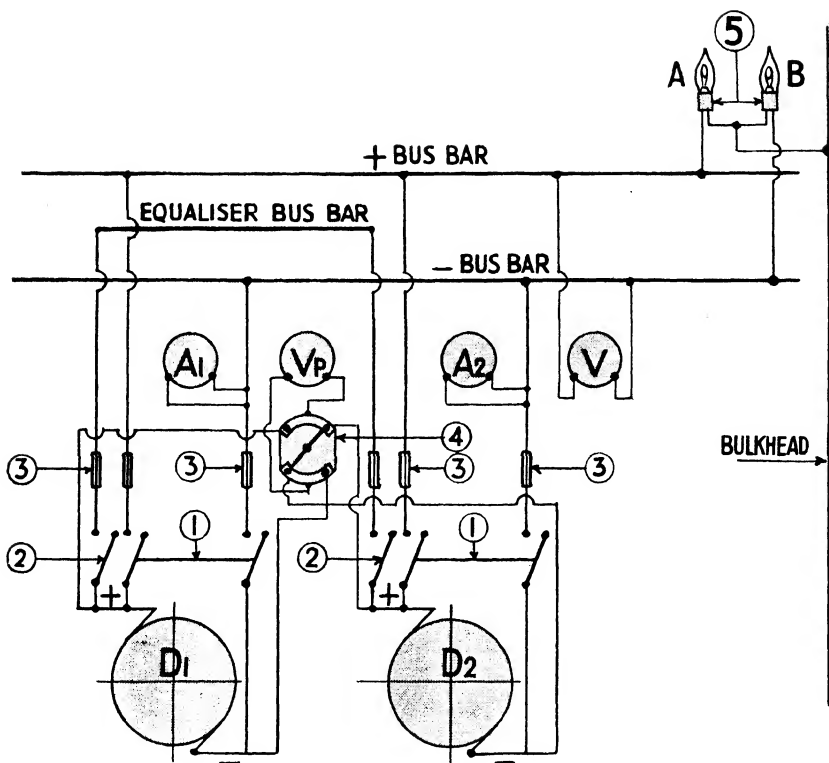
No. 679.—Switchboard Connections for Group of Dynamos.

(Two Compound Wound D.C. Generators, in Parallel.)

D_1, Dynamo No. 1.

D_2, Dynamo No. 2.

1, 1, Double pole switches (shown " open ").

A_1, Ampmeter of dynamo No. 1.

A_2, Ampmeter of dynamo No. 2.

2, Equaliser switches ("shown open ").

V, Voltmeter.

V_p, Equalising voltmeter to parallel both machines when starting up one machine at a time.

3, Fuses.

4, Two-way switch for voltmeter V_p.

5, Pair of earth lamps, A and B, to test for earth leakage.

The two-way voltmeter V_p is fitted with the object of ensuring that the voltage of the machine started up last is equal to that of the one started up first, previous to closing the equaliser switch and main switch of the latter, otherwise a tendency to "hunting" would occur, one machine driving the other as a motor. The equaliser switch requires to be closed just previous to closing the main switch.

Three or four generators can be coupled up exactly as shown for the two, but the voltmeter V_p would require to be fitted with a three- or four-way key switch to correspond. In the case of one dynamo of a group falling off in speed and in E.M.F., and so upsetting the balance, an automatic circuit breaker is sometimes fitted which acts electrically to cut out the faulty running machine.

Earth Lamps.

If leakage to earth (ship) is taking place from a positive wire, lamp A will burn dim and lamp B bright.

If leakage to earth (ship) is taking place from a negative wire, lamp B will burn dim and lamp A bright. See also p. 965.

Systems of Electric Wiring.
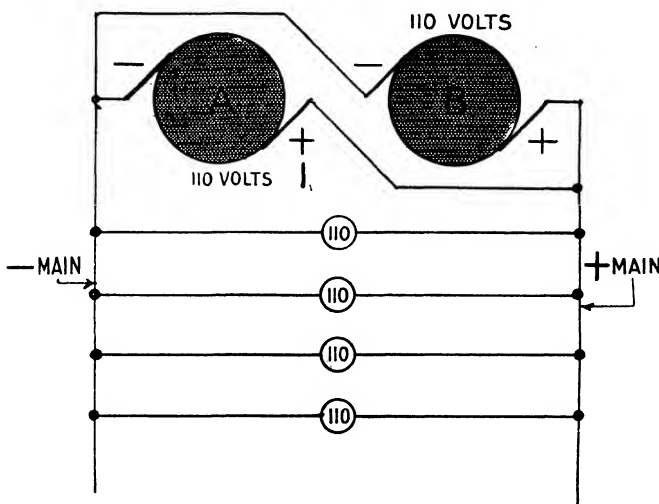
No. 680.—Two-Wire System.
(With 2 D.C. Generators coupled in Parallel.)

Each of the dynamos A and B (No. 680) generates current of 110 volts, and, being coupled in parallel, are each connected direct to the mains, thus giving an E.M.F. of 110 volts to all of the lamps, the amperes delivered being equal to the sum of the output of the two dynamos, say 22 kilowatts each; then total output = 22 × 2 = 44 kilowatts, or 44000 watts, as 44 × 1000 = 44000.

Again, 44000 watts ÷ 110 volts = 400 amperes.
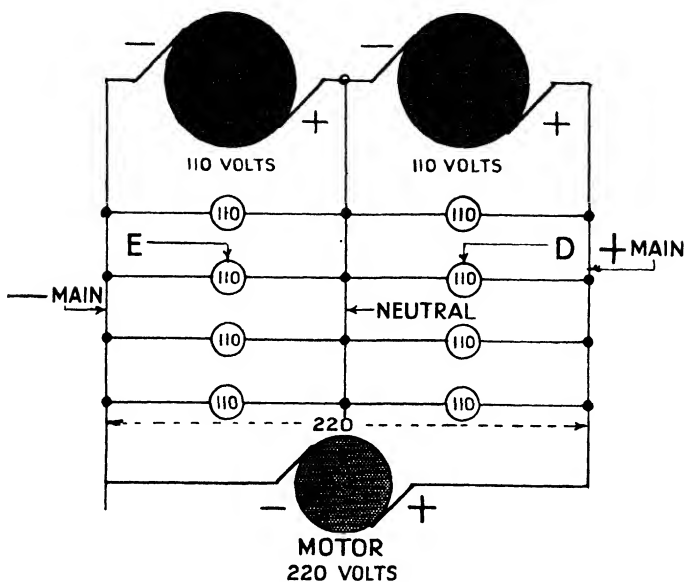
No. 681.—Three-Wire System.
(With 2 D.C. Generators coupled in Series.)

Two dynamos A and B (No. 681), each generating current of 110 volts, are coupled in series, so that the positive of dynamo A forms the negative of dynamo B, and as each produces an E.M.F. of 110 volts, the combined voltage is equal to 220 volts when taken across the outside mains. The central neutral wire, however, divides the E.M.F. into two, thus giving a voltage of 110 in each of the two lamps run in series as shown. The action of the neutral wire may be described as follows :—

1. If the distribution of lamps switched on is equal on either side of the neutral wire, no current will flow in this wire.

2. If, say, lamp D burns out or is switched off, then lamp E will be supplied by current from dynamo A by means of the neutral wire, which will thus act as a positive lead.

3. If, say, lamp E instead of lamp D burns out or is switched off, then lamp D continues to burn, as current will now flow from the lamp along the neutral to dynamo B, the wire thus acting as a negative lead.

4. If, say, a motor is coupled up between the two outside mains, the current supplied will be equal to 220 volts. It should be noted that similar results can be obtained by means of a *single* dynamo generating current of 220 volts, the neutral wire being then coupled to a regulating battery, the latter automatically equalising the voltage on either side of the neutral wire to 110 volts. See also p. 981.
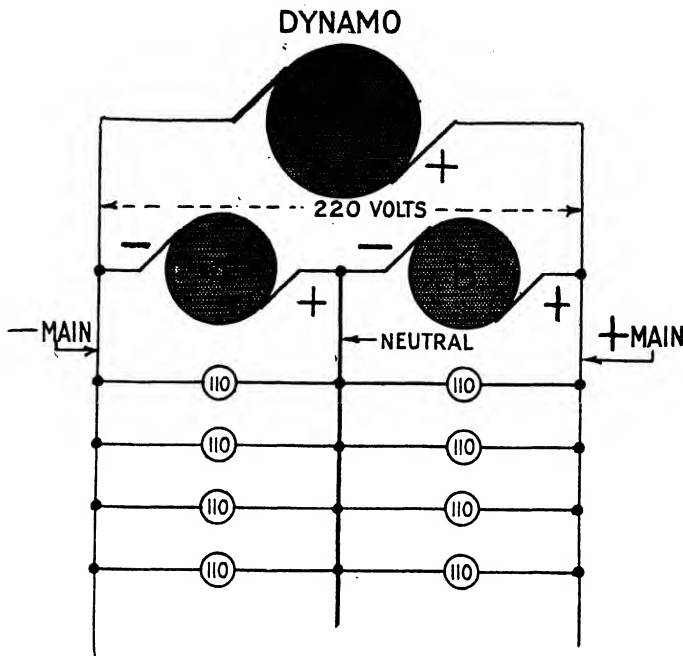
DYNAMO

No. 682.—Three-Wire System.
(With Single D.C. Generator and Balancer.)

The balancer consists of two dynamos, A and B, of exactly similar construction and coupled in series. With equal load on either side of the neutral wire the two dynamos take a small current from the mains and run lightly as motors. If, however, the load is unequal on either side, one of the pair functions as a motor and the other as a generator, to restore the balance. The action is somewhat as follows :—

1. If additional lamps are in use on, say, the positive main side, then dynamo B will tend to fall off in speed through want of current, and dynamo A will tend to increase in speed through increase of current, with the result that A will then act as a motor and drive B, which in turn will generate the additional current required to restore the balance.

2. If the load on the negative main side of the neutral wire is in excess, then dynamo A will tend to fall off in speed through want of current, and dynamo B will tend to increase in speed, with the result that B will now act as a motor, driving A, which in turn will generate the required additional current required to restore the balance.

NOTE.—It is of importance to note that, in the case of a generator, current enters the armature from the negative brush and leaves at the positive brush, while, in a motor, current enters the armature at the positive brush and leaves at the negative brush. The action takes place in the balancer described.
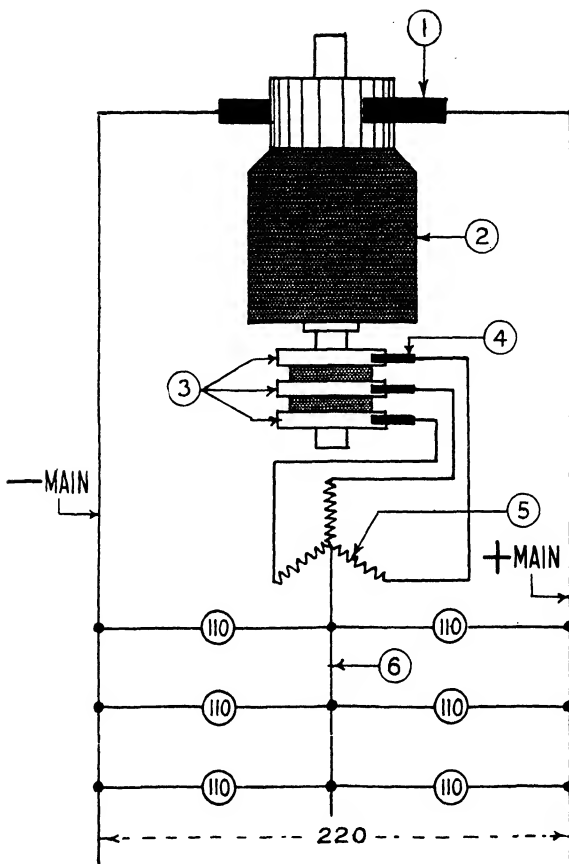
No. 683.—Three-Wire System, with Single D.C. Generator and Static Balancer.

1, Brushes.
2, Armature.
3, Armature extension.
4, Slip rings.
5, " Choking " coils of balancer.

An extension of the D.C. armature is fitted with three slip rings and brushes, the latter being connected up with three similar coils of wire wound on iron coils and forming what are known as " choking coils." Alternating current flows from the slip rings through the choking coils, and as the connections are made at three equi-distant positions of the armature, the centre one being at a point half-way between the D.C. brushes, the voltage will thus be maintained equal on either side of the neutral wire, no matter how unequally the load may be distributed.

Heating of Dynamos.

To prevent overheating of the armature conductors, air spaces are usually provided in the boss on which the coils are wound. Heating of the armature or magnet coils would result in additional load being thrown on the machine, as the conductivity of copper falls off with increase of temperature, so that fusing of the conductors might take place. For sudden rise of temperature in external conductors, fuses are fitted, those being composed of lead and tin, with a low temperature melting point. The fuses act as automatic circuit breakers and prevent damage to the main wiring. Tinned copper is now generally employed for fuse wire purposes. It may be stated that all electrical generators when running at full load tend to develop a rise of temperature in the conductors for the reason that work is being done by current flow. As mentioned previously, the effect of this is to increase the load on the machine.

Fuel Consumption for an Electrical Generator.

Assume that the volts are 110, and amperes, say, 200.

Then, $$\text{E.H.P.} = \frac{110 \times 200}{746} = 29.5.$$

Assume a steam-driving engine and oil-fired boilers, mechanical efficiency, say, 90 per cent.

Then, $$\text{Steam I.H.P.} = 29.5 \div .90 = 32.77,$$

and allowing a fuel consumption of, say, .98 lb. oil per I.H.P. hour.

Then, $$\text{Consumption} = \frac{32.77 \times .98 \times 24}{2240} = .344 \text{ ton per day.}$$

Simple Electrical Calculations.

Example 1.—A dynamo output is 44 kilowatts, at 110 volts: find the amperes, also the ohms resistance of the mains.

Then, $$44 \times 1000 = 44000 \text{ watts.}$$

$$\text{Amperes} = \frac{44000}{110} = 400.$$

$$\text{Ohms} = \frac{\text{volts}}{\text{amperes}} = \frac{110}{400} = .275.$$

Example 2.—Two generators are coupled in parallel, each giving out 22 kilowatts at 110 volts: find the amperes output.

Then, $$\frac{22 \times 1000 \times 2}{110} = 400 \text{ amperes at 110 volts.}$$
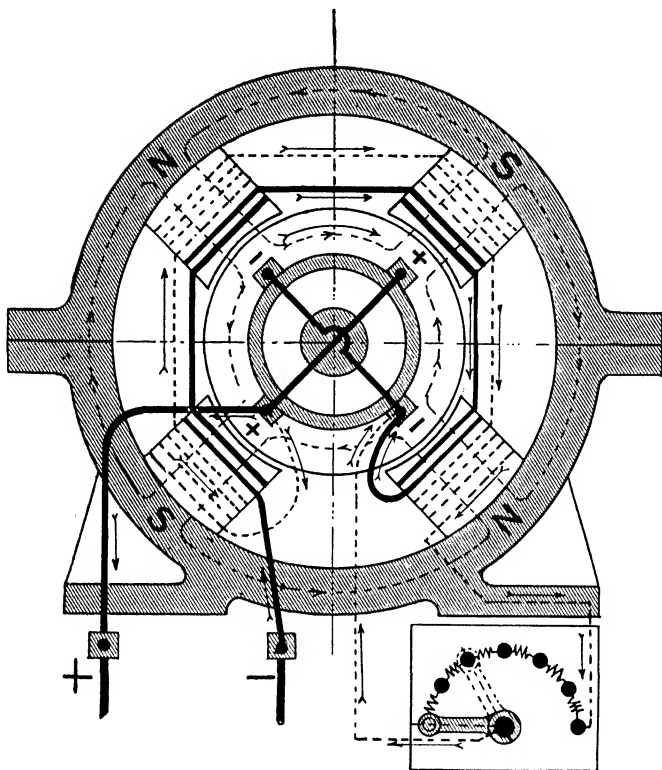
No. 684.—4-Pole Direct Current Electrical Generator.
(With Shunt Field Regulator.)

Arrows indicate the passage of the lines of magnetic force from and to the north and south poles of the machine, and other arrows show the flow of the current generated in the series and shunt windings, the heavy lines representing the series coils and the dotted lines the shunt coils.

The rheostat regulator shown is fitted to permit of variation in the strength of the shunt field according to required conditions of load. The position of the resistance handle, as shown shaded, takes in the full resistance of the coils and weakens the shunt field strength, while in the position shown by the dotted lines two of the resistance coils are cut out and the shunt field strength would then be slightly increased.

With the shunt regulator handle over on the extreme right-hand stud, all of the resistance coils would be cut out and the shunt field would then function at maximum strength for the load carried, or to "raise volts."

When "interpoles" or "commutator poles" are provided and wound in series with the main poles of the machine, a sparkless position of the brushes is obtained without having to "rock" the latter.

The positive brushes are in line with the south pole magnets and the negative brushes in line with the north pole magnets.

It should be noted that the mechanical production of electricity requires the use of magnetic lines of force, and in a dynamo these are provided for by the previously magnetised pole pieces of the machine.

As the armature revolves, the existing lines of magnetic force are cut by the conductors, and currents are induced to flow within the conductors from end to end, thence to the commutator bars and brushes.

1, Main switch and fuse
   block.
2, " Off " stop.
3, Resistance con-
   tactors.
4, "Overload" magnet
   which functions to
   short circuit this
   "no volt" magnet.
5, " No volt " release
   magnet.
6, Sliding contact.
7, Reversing switch.
8, Shunt field.

No. 685.—Starter and Reversing Switch for Shunt Motor.
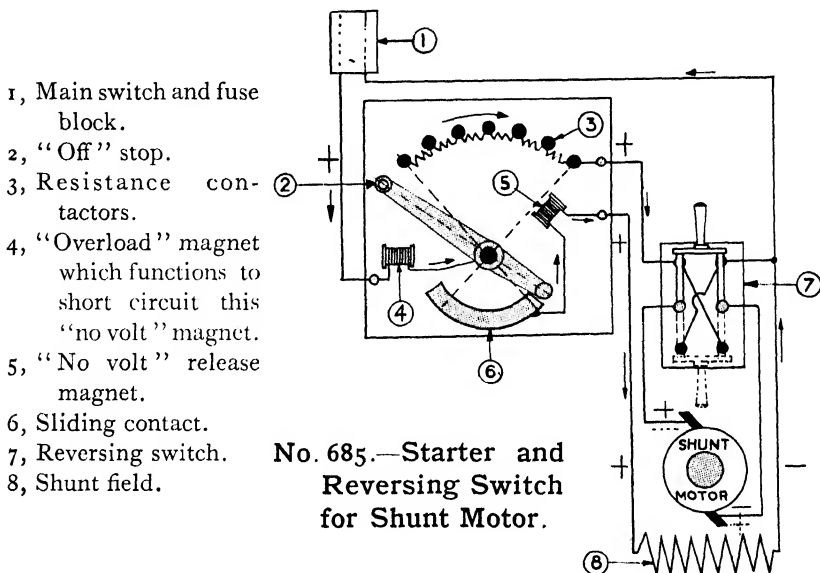
Action.—The handle as shown is in " off " position, but when moved over to the first resistance contactor on left, current is admitted at full strength into the field by way of the overload and no load magnets, and into the armature at reduced voltage through the series of resistance coils. When the handle is on the last contactor on right, current is being admitted to the armature at full strength, the other end of the handle still remaining connected with the large sliding contactor below, and through which the field current is supplied continuously. On examining the sketch of the reverser switch, it will be evident that the full lines indicate the flow of the current to the brushes for one direction of rotation, and the dotted lines show the double switch handle pulled over and the current flow reversed at the brushes, the field current direction of flow remaining unchanged. A motor can be reversed by changing the direction of current flow in either the brushes (as above) or the field, but not in both at once. The motor is stopped by means of a push button (not shown in sketch), which short circuits the current and brings the machine to rest by releasing the handle from the " no volt " magnet on right.

NOTE.—A shunt-wound motor runs at practically constant speed at all loads.
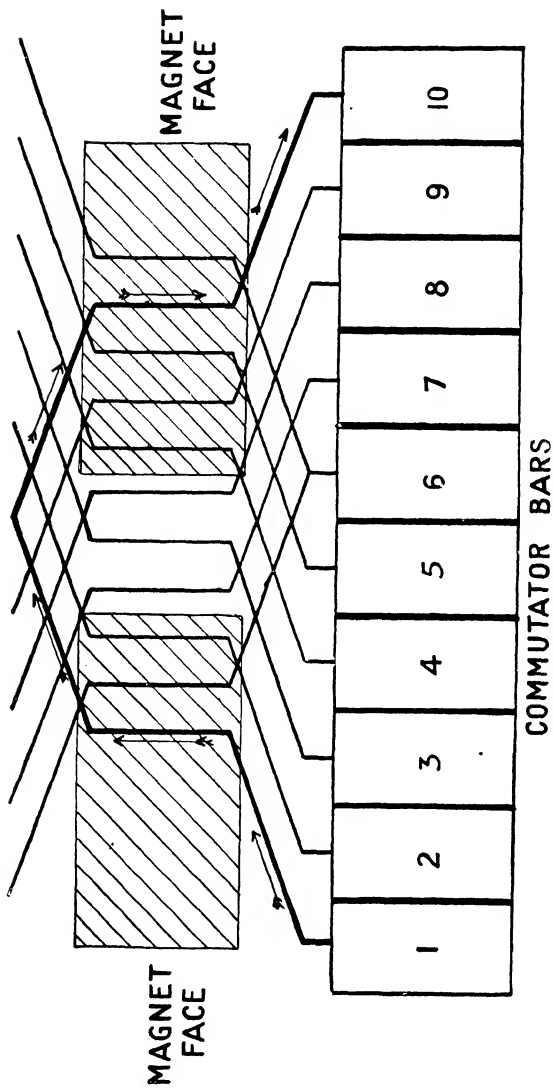
No. 686.—Diagram of "Wave" Winding for Two Pole Machine (Commutator opened out or laid out flat).

No. 687.—Double Wire System of Electric Lighting.

CONTACT PLUG

BULKHEAD

NEGATIVE

PORTABLE LAMP

POSITIVE

BULKHEAD

NEGATIVE

SWITCHBOARD

POSITIVE
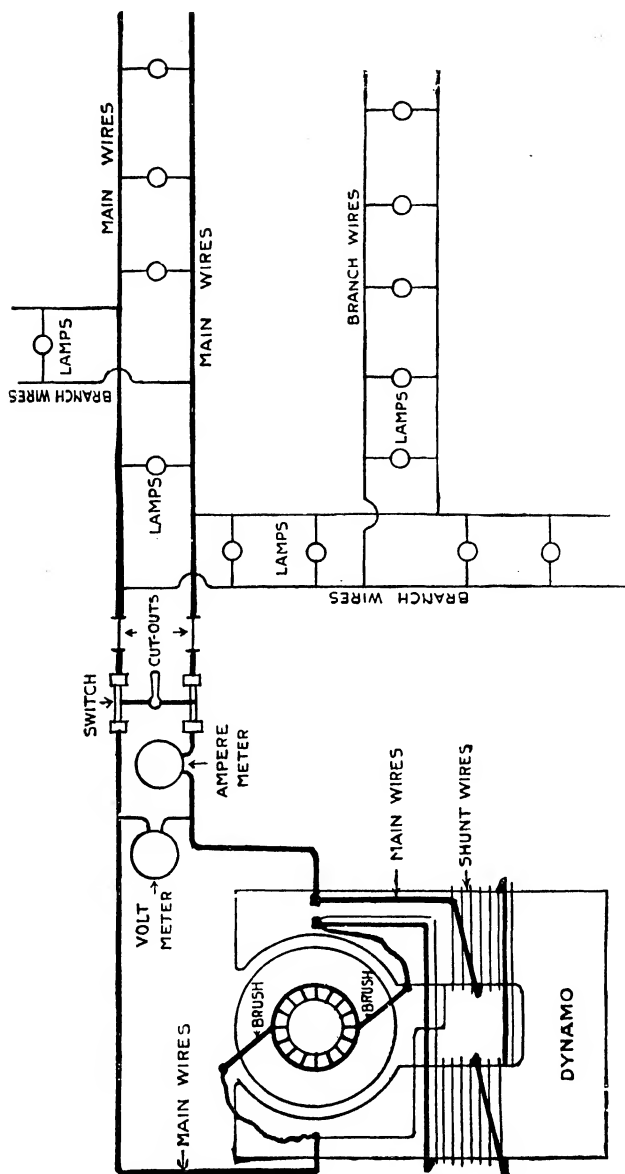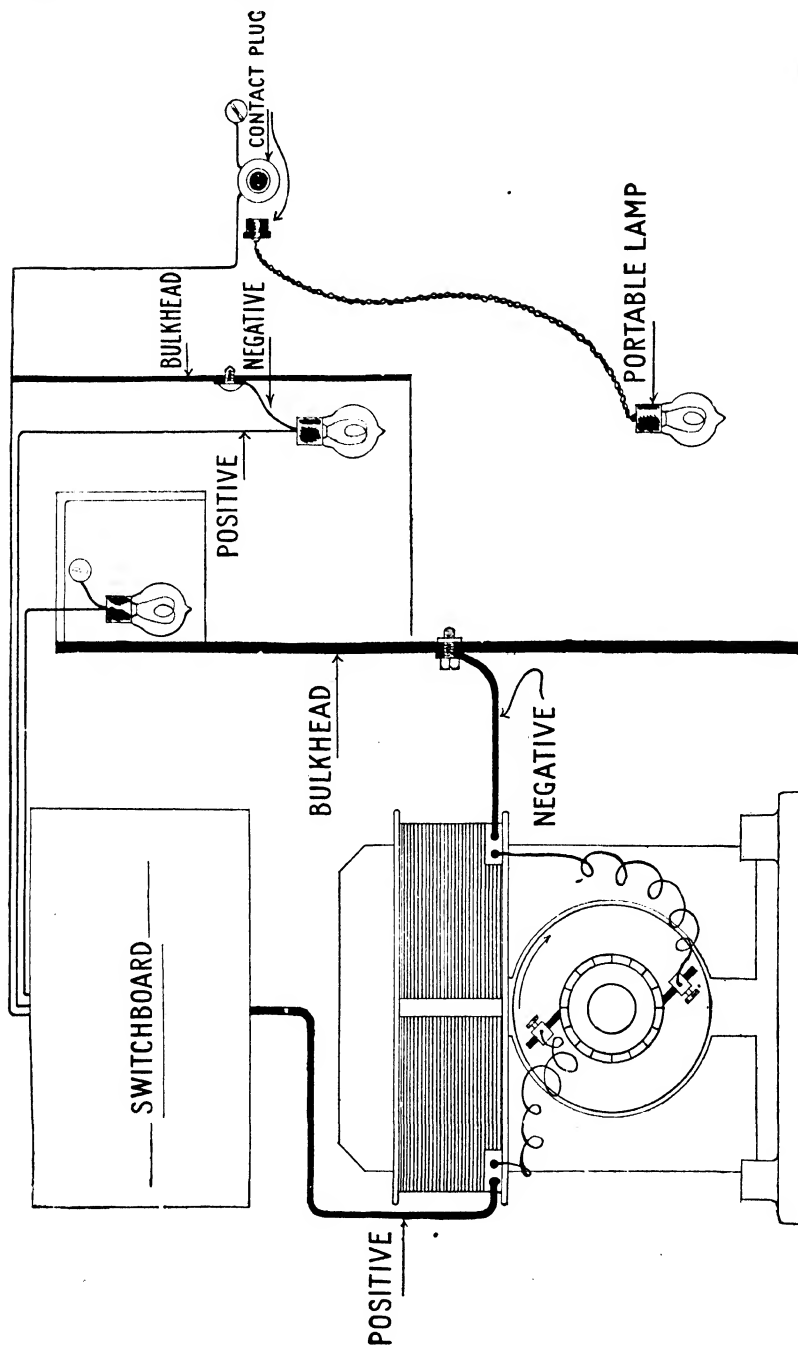
No. 688.—Single Wire System.

D.C. Electrical Generators and Motors.

An **Electrical Generator** is employed to convert mechanical energy into electrical energy, a mechanical transmission loss of about 10 or 12 per cent. taking place. When the armature is mechanically revolved in the field space it is exerted to cut through the resisting lines of magnetic force in the field, and when this takes place current is generated within the armature conductors, and flows from end to end of same, a B.E.M.F. being also developed. It is necessary that the magnets should possess a certain quantity of initial magnetism, without which the machine would fail to generate when started up.

$$\text{Generator efficiency} = \frac{\text{E.H.P. output}}{\text{Mechanical B.H.P. input}} = 88 \text{ per cent. (average)}.$$

An **Electrical Motor** is employed to convert electrical energy into mechanical energy, an electrical transmission loss of about 10 or 12 per cent. taking place. When starting up it is necessary to first excite the field before admitting the full current strength to the brushes, a set of resistance contactors being fitted for this purpose on the starter and through which the current is admitted gradually to the brushes and armature. If this precaution were neglected the armature conductors might fuse owing to the initial low resistance offered to current flow. By first exciting the field, lines of force are created which function to build up the required B.E.M.F. by rotation of the armature, and which gives a high starting torque. In a dynamo the movement of the armature conductors *oppose* the direction of the force produced electrically in the field, whereas in a motor the armature conductors move *with* the direction of the force produced electrically in the field.

Under load conditions, if the supply voltage is, say, 110 volts, the B.E.M.F. due to armature rotation voltage may be, say, 50 volts, the difference between the two being accounted for by the mechanical power developed, and in which electrical energy is converted into mechanical energy.

$$\text{Motor efficiency} = \frac{\text{Mechanical B.H.P. output}}{\text{Net E.H.P. input}} = 88 \text{ per cent. (average)}.$$

NOTE.—If a resistance is inserted in the shunt field of a motor, the weakening of the field strength will result in *increase* of armature speed.

Electrical Circuit Breaker or Automatic Switch.

This device takes the place of heavy fuses on the switchboard, and automatically cuts out the current when overload occurs. Connection can afterwards be made at once by hand lever action and without the loss of time required to remove and replace blown fuses, etc.

Action Described.

Current from the generator flows through the solenoid coils (4) and the connecting bar (15), thence across the main copper contacts to supply the main circuits. The switch is closed by moving the handle upwards against the compression of springs (3) and (7), until the toggle lever is caught and held in position by means of the latch (6), trigger, and small roller (11).

If the current becomes excessive the solenoid coils are energised, and, becoming magnetic, act to draw up the iron core plunger, the top end of which pushes up the trigger arm and releases the toggle lever (8), which when thus freed allows the action of springs (3) and (7) to operate and force the copper switch contacts away from those of the switchboard, and thus break the circuit. The small auxiliary carbon contacts (2) shown at the top, and in series with the main contacts (1), are arranged to open last and make first, and these function to minimise heavy sparking at the main contacts when the arc is broken.

The switch can also be operated for either opening or closing, as required, by means of the double handle (13).
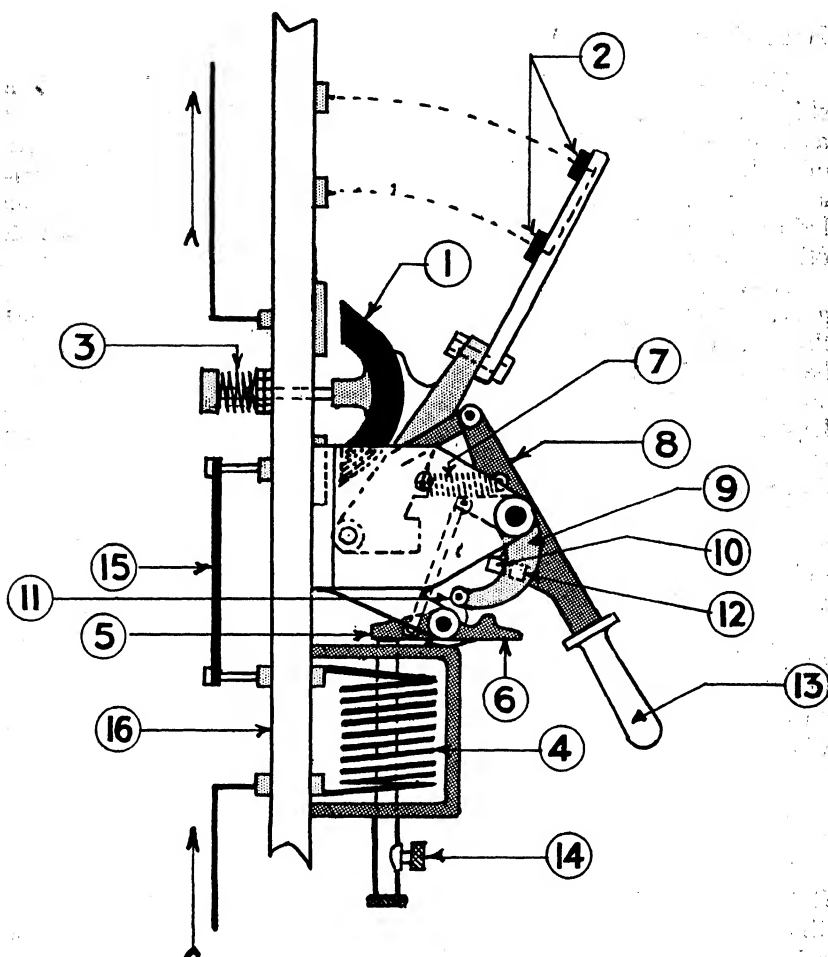
No. 689.—Electrical Circuit Breaker or Automatic Switch.

(As fitted on Switchboards.)

1, Main copper contacts.
2, Auxiliary carbon contacts.
3, Spring to hold switch in " open "
    position.
4, Solenoid with iron plunger core.
5, Trigger release.
6, Latch.
7, Spring.
8, Toggle lever.

9, Loose lever.
10, Stop on toggle lever.
11, Small roller.
12, Stop on loose lever.
13, Handle of toggle lever.
14, Adjustment for plunger lift.
15, Connecting bar.
16, Switchboard.

Electrical Accumulators or Storage Batteries.*

The storage battery is a very important component of the modern ship's electrical installation. It is rapidly coming to be regarded as an essential auxiliary, as an emergency device, and as a conserver of fuel. The factor of reliability is obviously of paramount importance, and on this score alone the possibility of using batteries has led to the adoption of electricity for many marine services, for which otherwise it might not have been considered.

A typical example of this is the electrical operation of steering gear. Electricity provides here a more flexible means of control than any other, but it might be urged that a failure of supply would be more serious, and more likely to occur with electrical than with steam operation. The addition of a battery, however, which can be kept floating in a fully charged condition across the power supply mains, ensures a definite continuity of supply in the event of breakdown, which is not equalled by any other means of operation.

The use of electricity for lighting purposes on board ship is another very important instance. Its widespread adoption is due to its safety, its ease of control, and the facility with which the supply can be distributed to all quarters of the vessel. The function of the storage battery here is, in the first place, to provide continuity of supply in emergency, thus preventing the possibility of panic, and insuring non-interruption of the essential services of the ship. As an example of the best practice the modern Exide-Ironclad battery, whose construction is illustrated in these pages, may be taken.

Exide-Ironclad Battery.

This well-known type of battery is manufactured by Messrs The Chloride Electrical Storage Co. Ltd., and the cells are essentially different in construction from those using ordinary flat plates. The principle on which the positive plates are built up precludes "growth" or buckling of the plates, assures low internal resistance, and permits of very high discharge currents without undue drop of voltage.

In the Exide-Ironclad positive plate the active material is enclosed in slitted ebonite tubes, and is thus held securely in contact with the grid which conducts the current to the terminals. The slitting of the ebonite is of so fine a nature that the electrolyte is allowed free diffusion to the active material, but the latter cannot fall away from the tube. The plate is thus maintained in a constant state of maximum efficiency.

* Information and illustrations referring to batteries supplied, by kind courtesy of Messrs The Chloride Electrical Storage Co. Ltd., Clifton Junction, Manchester.
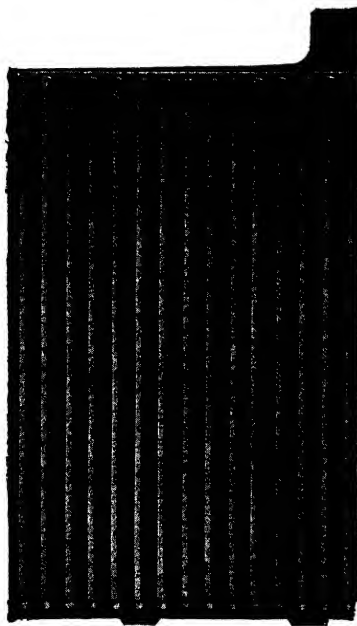
No. 690.—Exide-Ironclad Positive Plate.
(Messrs The Chloride Electrical Storage Co. Ltd.)
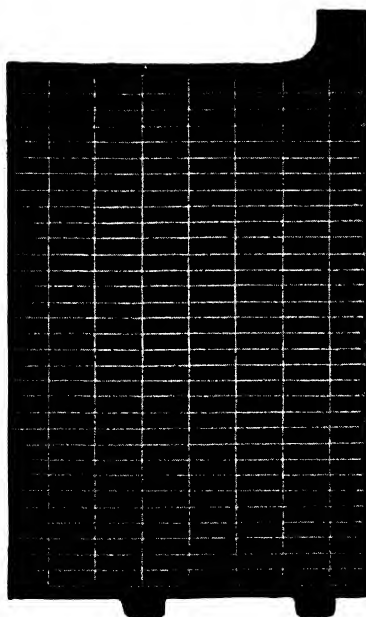
No. 691.—Exide-Ironclad Negative Plate.
(Messrs The Chloride Electrical Storage Co. Ltd.)

The negative plate consists of a hard lead-alloy grid with a lattice structure, forming a flat cage which securely holds the active material in the form of continuous strips. The intimate contact between the grid and the active material ensured by this method of construction results in low internal resistance, and renders the plate unaffected by vibration or other mechanical stresses.

The separation of the plates in the cells is effected by special separators, made of a selected quality of durable wood. In the
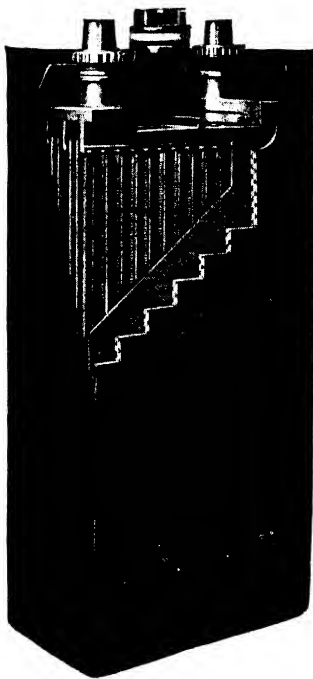
No. 692.—Exide-Ironclad Cell cut away to show Construction.

. (Messrs The Chloride Electrical Storage Co. Ltd.)

course of manufacture this is subjected to a carefully developed process which eliminates all constituents which would be injurious to the battery.

General.—An accumulator or electrical storage battery is employed to transform electrical energy into chemical energy when being charged, and to liberate the same in the form of electrical energy when discharging.

The simple accumulator consists of a number of separate two-plate cells, each filled up with dilute sulphuric acid of about
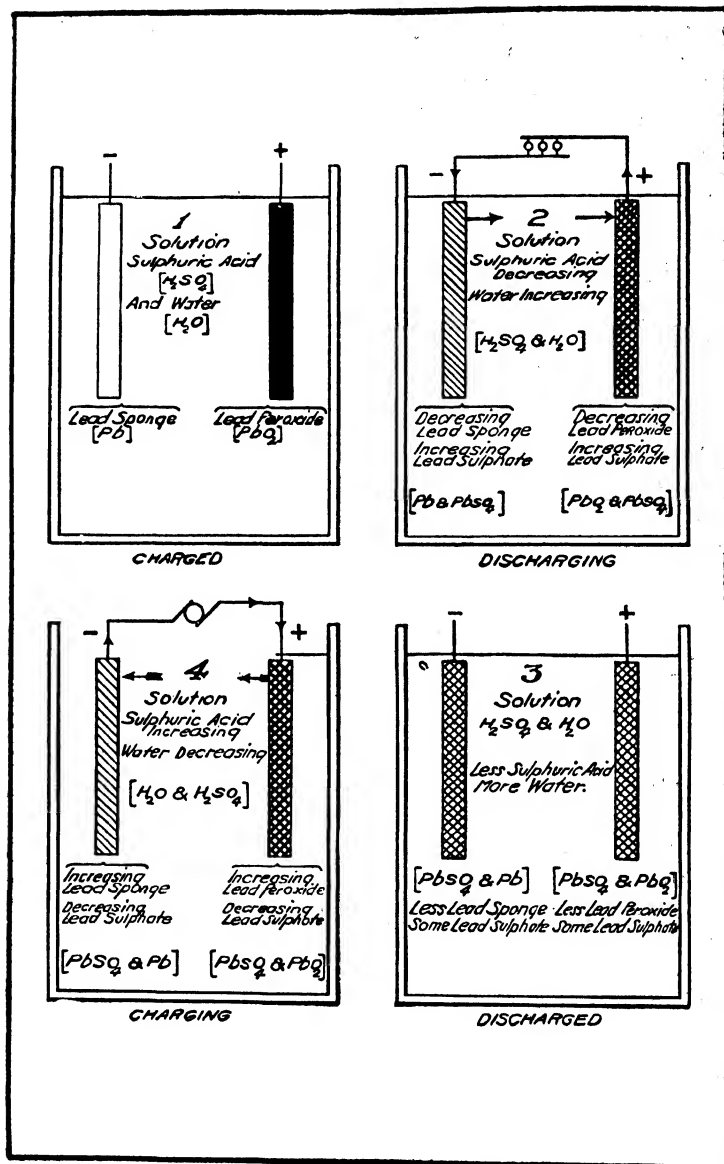
No. 693.—Fundamentals of a Storage Battery.

The four illustrations show clearly the chemical changes which take place in a single cell during charging and discharging, also the conditions which exist when fully charged and when idle or in open circuit. Observe that when discharging the electrical current flows through the liquid from the negative plate to the positive plate, and from the latter to the outer circuit.

1·2 sp. gr. by hydrometer test. Each cell consists of a pair of lead plates, and each cell may be connected up in series or in parallel as required. If in series the voltage is increased, and if in parallel the voltage remains constant at 2 volts, the effective E.M.F. of each cell being equal to about 2 volts, and the capacity in ampere hours depends on the area and thickness of the positive lead plates which form the cell and number of plates provided. The positive plates hold peroxide of lead and the negative plates soft, spongy lead, the two plates being spaced apart from each other in the solution by means of wood or glass separators.

The battery is charged through the medium of a shunt-wound D.C. dynamo, the E.M.F. of which should be about 35 per cent. in excess of the battery E.M.F. discharge.

Simple Calculations.

Example 1.—Find the capacity of a cell which consists of, say, 8 positive plates, 9 in. by 6 in., taking an average allowance of, say, 50 ampere hours per sq. ft. of positive plate effective area.

Then $$\frac{9'' \times 6'' \times 2 \times 8 \times 50}{144} = 300 \text{ ampere hours.}$$

NOTE.—Both sides of the positive plates are counted as effective surface. If on discharging the current flow is, say, 2 amperes, then the battery should last for 150 hours, as $300 \div 2 = 150$ hours. The capacity or output in ampere hours, it should be noted, increases the longer the period taken for discharge.

Example 2.—The required voltage of a battery is to be 80 volts: find the number of cells which require to be joined up in series to obtain the E.M.F., allowing 1·84 volts effective E.M.F. per cell for discharge.

Then, $80 \div 1.84 = 43.4$, say 44 cells.

Example 3.—Find the dynamo charging voltage required for the battery in Example 2.

NOTE.—Allow a charging voltage of 2·6 volts per cell.
Then, $44 \times 2.6 = 114$ volts at dynamo.

General Notes on Batteries.
Charging.

1. Batteries should be neither undercharged nor overcharged.

2. When charging, have correct voltage at the shunt dynamo before switching in, and when stopping first switch off battery.

3. The positive wire of the dynamo is to be connected to the positive terminal of the battery, also negative to negative.

4. The charging rate for a battery is usually equal to about one-tenth of the ampere-hour output, that is if the output is, say, 50 ampere hours, the charging current would require to be 5 amperes for 10 hours, or $2\frac{1}{2}$ amperes for 20 hours, as $5 \times 10 = 50$, also $2\frac{1}{2} \times 20 = 50$.

5. When a battery is fully charged, the acid appears to boil, and turns milky.

6. During the charging process, gas is generated, caused by the chemical action set up, which results in the liberation of hydrogen at the negative plate, and of oxygen at the positive plate.

Maintenance.

7. The electrolyte or sulphuric acid solution requires to possess a specific gravity of 1·21 by hydrometer test.

8. Batteries should be kept fully charged, and idle batteries should be charged up full about once weekly.

9. Each cell should be tested regularly for voltage and specific gravity, and any faulty cell should be given special charging.

10. Pure fresh water requires to be added sufficiently often to keep the plates covered with electrolyte, another name for the acid solution.

11. The positive plates of a battery are dark brown in colour, and the negative plates are grey in colour.

12. Cells should not be left for long periods in a condition of complete discharge, or of nearly complete discharge, as this results in heavy sulphation.

13. Any metallic substance lying across the two plates of a cell will set up a short circuit and ruin the cell.

14. When batteries are to be put out of service for a period not exceeding, say, three months, the cells require to be fully charged until the positive plates assume a deep chocolate colour, and free gassing is taking place.

15. The level of the liquid acid always requires to be above that of the top edge of the plates.

16. By the term " Anode " is meant the positive plate of a cell, and by " Kathode " the negative plate.

17. The specific gravity of the acid solution when tested by hydrometer affords an accurate index as to the condition and functioning of the cells.

Discharging.

18. When discharging, cells should not be allowed to run down below 1·7 volts.

19. When discharging, the acid solution loses in specific gravity, varying in extent according to the type of battery.

20. High rates of discharge will not affect the plates.

21. Sulphating consists in the formation of white sulphate on the plates, which reduces the efficiency of the battery.

22. Excessive discharges (*i.e.*, running too long between charges) should be avoided.

23. In cases of bad sulphating of plates the remedy is to carry out prolonged charging at low rates.

Efficiency.

24. The current efficiency of a battery may be expressed as follows :—

$$\text{Ampere hour efficiency} = \frac{\text{Ampere hours given out during discharging}}{\text{Ampere hours put in during charging}}.$$

25. The working efficiency ranges from about 85 to 90 per cent. at normal rates, and varies according to the amount of work the battery does. The charging and discharging rates per square foot of positive plate surfaces for Chloride Company batteries are given as follows :—

Charge—Normal = 8 amperes ; maximum = 15 amperes.

Discharge—

Time in Hours.	Amperes per Square Foot.	Capacity in Ampere Hours.	Final Voltage.
1	30	30	1·65
3	15	45	1·75
6	9	54	1·8
9	6⅔	60	1·85

It should be noted that, referring to the discharge rate, the ampere hours' capacity ranges from 30 for a 1-hour discharge rate to 60 for a 9-hour discharge rate.

Referring to " Exide " batteries, the capacity, dimensions, and charging current are given as follows for plates of medium size :—

Plates $= 8\frac{7}{16}$ in. by $8\frac{7}{16}$ in. by 9·6 mm. thick for positive plates, and 6·4 mm. thick for negative plates.

Capacity in ampere hours per positive plate area when discharging :—

In 10 hours $= 40$ ampere hours.
,, 5 ,, $= 33\frac{1}{3}$,, ,,
,, 3 ,, $= 25·6$,, ,,
,, 1 hour $= 20$,, ,,

Charging current per positive plate $=$ 5·5 amperes at normal.
,, ,, ,, ,, $= 11$,, ,, maximum.

Examples of Batteries.
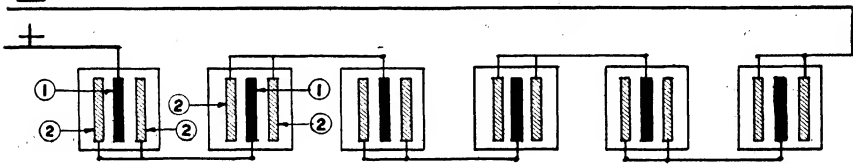
No. 694.—Single Cells in Series.

(1 positive plate and 2 negative plates.)

Positive plate area $= 9$ in. by 6 in.

Allow for " Exide " batteries 55 ampere hours per square foot positive plate total effective area (both sides) at 10-hour discharge rate.

Then,   E.M.F. $= 6 \times 2 = 12$ volts.

$$\text{Capacity} = \frac{9'' \times 6'' \times 2 \times 55}{144} = \begin{cases} 41·25 \text{ ampere hours at 10-hour} \\ \quad\quad \text{discharge rate.} \end{cases}$$

Watt hours $= 12 \times 41·2 = 494·4$
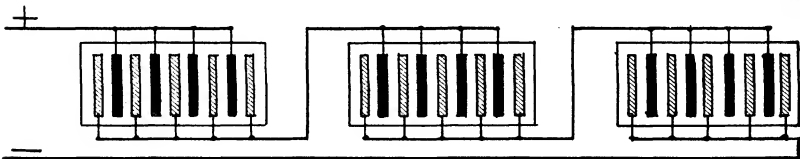
No. 695.—Grouped Single Cells in Series.

(Plate dimensions as before (4 positive plates and 5 negative plates).)

Then,   E.M.F. $= 3 \times 2 = 6$ volts.

$$\text{Capacity} = \frac{9'' \times 6'' \times 2 \times 4 \times 55}{144} = \begin{cases} 165 \text{ ampere hours at 10-hour} \\ \quad\quad \text{discharge rate.} \end{cases}$$

Watt hours $= 6 \times 163·5 = 981.$
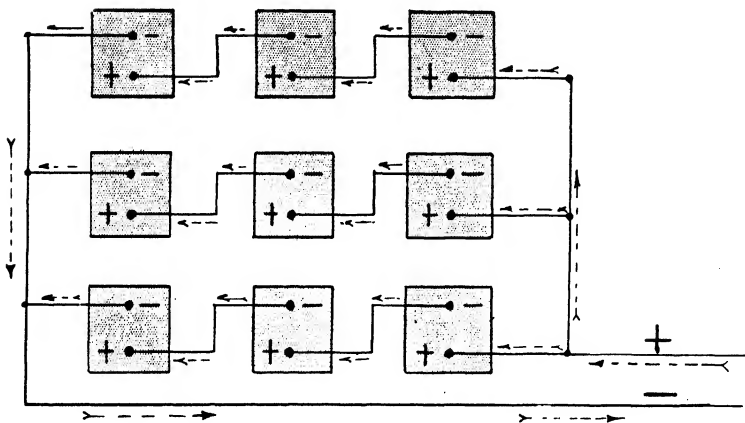
No. 696.—Parallel-Series Grouped Accumulator Cells.

Each cell = 2 volts.

Then, 2 × 3 = 6 volts E.M.F.

Allowing, say, 50 ampere hours per square foot of double-side positive plate area at 10 hours' discharge rate. Then ampere output = 50 × 3 = 150 ampere hours, or for, say, 10 hours, 150 ÷ 10 = 15 amperes per hour.

Watt-hours = 15 × 6 = 90 watt-hours.

NOTE.—The arrows show the current flow when charging the cells from a shunt wound dynamo.

When in action and discharging, the arrows will register in the opposite direction for the current flow. If the accumulator battery be increased to, say, 60 cells in series and 30 cells in parallel, then the output would be as follows:—

$$2 \times 60 = 120 \text{ volts E.M.F.}$$
$$50 \times 30 = 1500 \text{ ampere hours,}$$

or at 10 hours' discharge rate, then 1500 ÷ 10 = 150 amperes per hour.

NOTE.—The last arrangement referred to would be suitable for emergency steering gear purposes assuming the E.H.P. of the "Hele-Shaw" pump motor to be, say, 22.

$$\text{As,} \qquad \text{E.H.P.} = \frac{110 \times 150}{746} = 22 \text{ E.H.P.}$$
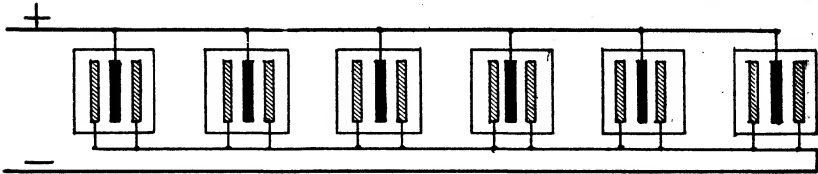
No. 697.—Single Cells in Parallel.

Then,   E.M.F. = 2 volts.

$$\text{Capacity} = \frac{9'' \times 6'' \times 2 \times 6 \times 55}{144} = \left\{ \begin{array}{l} 247 \text{ ampere hours at 10-hour} \\ \text{discharge rate.} \end{array} \right.$$

Watt hours = 2 × 247 = 494.
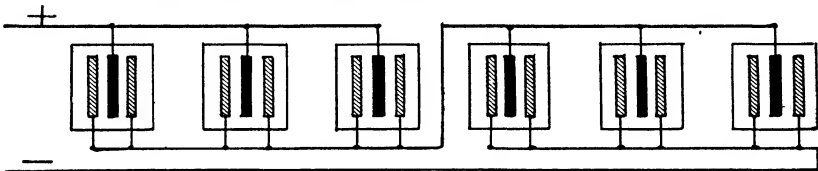
No. 698.—Single Cells in Parallel Series.

Then,   E.M.F. = 2 × 2 = 4 volts.

$$\text{Capacity} = \frac{9'' \times 6'' \times 2 \times 3 \times 55}{144} = \left\{ \begin{array}{l} 123.7 \text{ ampere hours at 10-hour} \\ \text{discharge rate.} \end{array} \right.$$

Watt hours = 4 × 123.7 = 494.8.

Referring to marine practice in which the usual line voltage is 110 volts, then—

In case No. 694 and at same capacity as before—

Number of cells required = $\frac{110}{1.84}$ = 59.7, say 60 cells.

In case No. 695 and at same capacity as before—

Number of cells required = $\frac{110}{1.84}$ = 59.7, say 60 cells.

In case No. 697 and at same capacity as before—

Number of cells required = $\frac{110}{1.84}$ = 59.7, say 60 cells

In case No. 698 and at same capacity as before—

Number of cells required = $\frac{110 \times 3}{1.84}$ = 125 cells.

Marine Emergency Supply System.

It is very desirable to have on a modern vessel some emergency power or lighting standby, and the amount of this provision depends on the exact details of the control gear, etc., on board the vessel. Where the steering is controlled from an auxiliary generator, there is always the possibility of this accidentally shutting down through some fault at a difficult moment, such as when negotiating a dock entrance or navigating a difficult river channel. In diagram No. 699 a system of control for an emergency storage battery is shown for use in conjunction with a 220-volt D.C. ship circuit.

A. A/B. Change-Over Contactor
B. Sectionalising Contactor
C. Quick Change Resistance
D. Trickle Change Resistance
M.V.R. Minimum Voltage Relay.
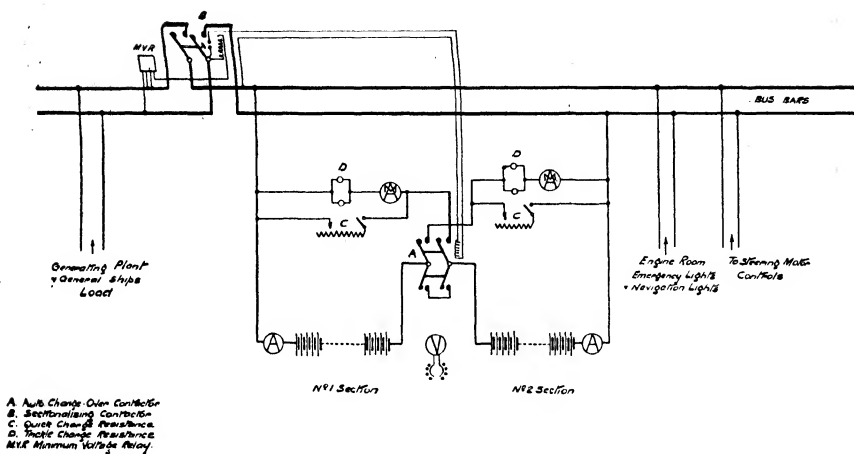
No. 699.—Ship's Emergency Battery Scheme for Lighting and Steering.

The 220-volt bus bars are divided into two portions, one of which is normally supplied from the generating plant and to which portion is connected the general ship's load. The other portion, separated when required by contactors or circuit breakers, supplies only that part of the load which is required to be carried by the battery in an emergency.

The bus bar contactors, or circuit breakers, separate the two sections of bus bars when the bus bar voltage falls by a predetermined amount through the action of the relay shown. Immediately this occurs, the automatic change-over contactor in the battery circuit changes over by spring action and connects the whole battery directly across the bus bars. So long as there is a supply of normal voltage on the bus bars from the generator, the battery contactor remains closed to the upper position by the action of the closing coil, and the two halves of the battery receive a continuous trickle charge through the duplicate sets of trickle charge resistances usually supplied in the form of lamps. When it is necessary to replace capacity after an emergency discharge, heavier resistances supplement the trickle charge resistances, allowing more current to pass, these being switched in by hand as a rule.

The battery is continuously trickle charged at a very low rate, just sufficient to counteract the open circuit loss that would otherwise take place, and high resistances are provided for this purpose, usually in the form of lamps. An alternative higher rate is available by the operation of the appropriate switches when the battery is required to be charged quickly. The battery is charged in two halves in parallel circuits from the 220-volt D.C. system.

Automatic switches instantly connect the battery all in series and throw it across the 220-volt bus bars when the normal supply to the bus bars fails, and at the same instant that section of the bus bars where supply is to be maintained from the battery is automatically isolated from the general bus bar load to avoid overloading the battery unnecessarily.

A, Main switch.
B, Main fuses.
C, Change-over contactor.
D, Ammeter.
E, Milliammeter.
F, Lamps.
G, Quick charge switch.
H, Voltmeter.
J, Voltmeter switch.
K, Battery.
L, Emergency lights.
N, Quick charge resistance.
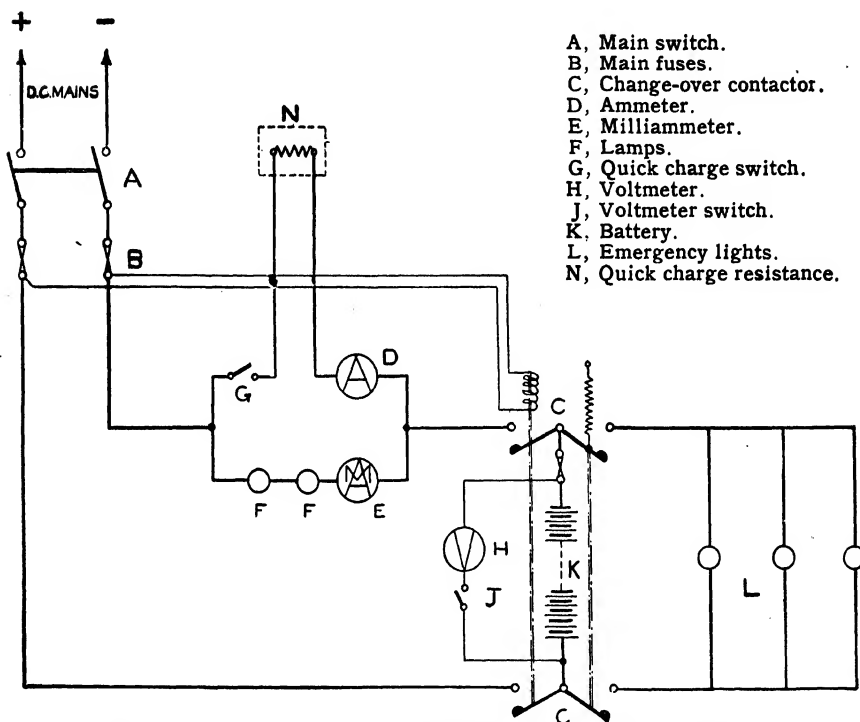
No. 700.—Theoretical Diagram for Small Patent "Keepalite" Installation for Engine-room or Boat Deck.

In this system the lights to be fed from the battery in an emergency are of a low voltage only, and so long as the ship's electricity supply remains normal, the battery contactor C remains closed to the charging position through the action of the coil, and receives a continuous trickle charge through the lamp resistances F, which again can be supplemented through switch G and quick charge resistance N after the battery has been discharged. The contactor changes over to the emergency position by the action of a spring if the main electricity supply fails, and thus lights up the pilot or emergency lighting circuit L from the battery, this circuit not being used at any other time. The contactor is self-resetting to the normal charging position when the main supply is resumed.
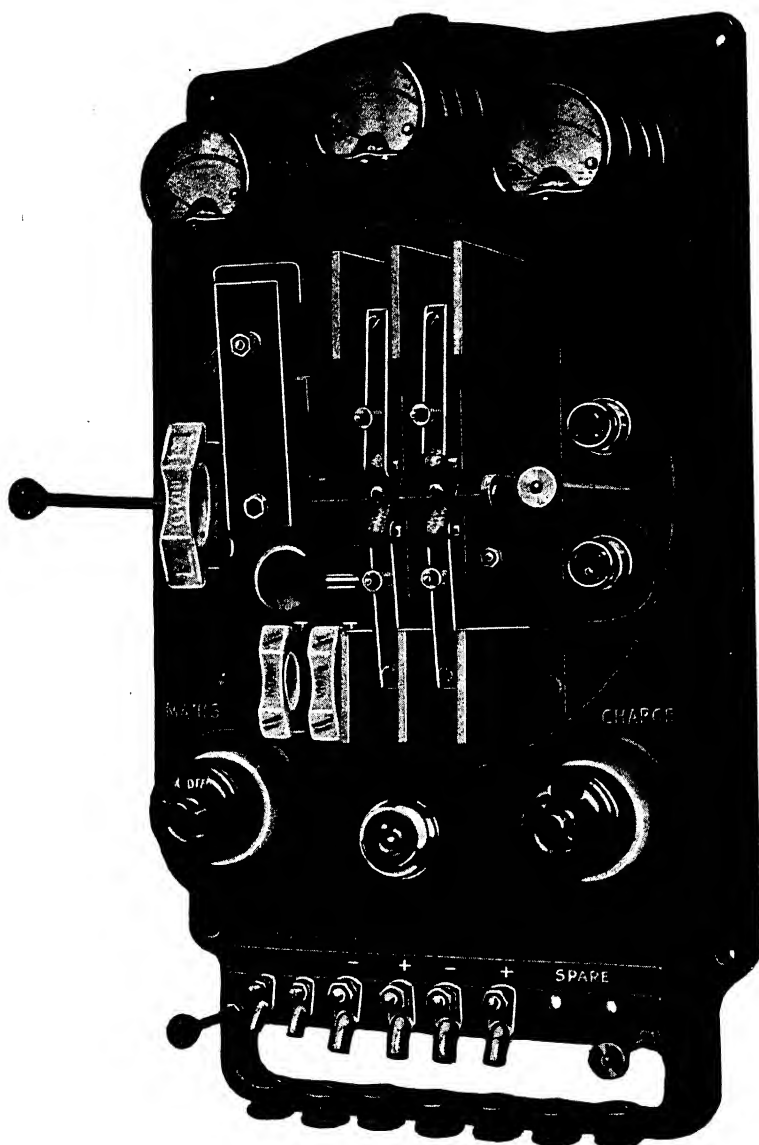
No. 701.—Patent " Keepalite " Panel with Covers
Removed

This illustrates the panel of the system just described, it being shown
with the circular contactor cover and terminal box cover removed to show the
working parts.
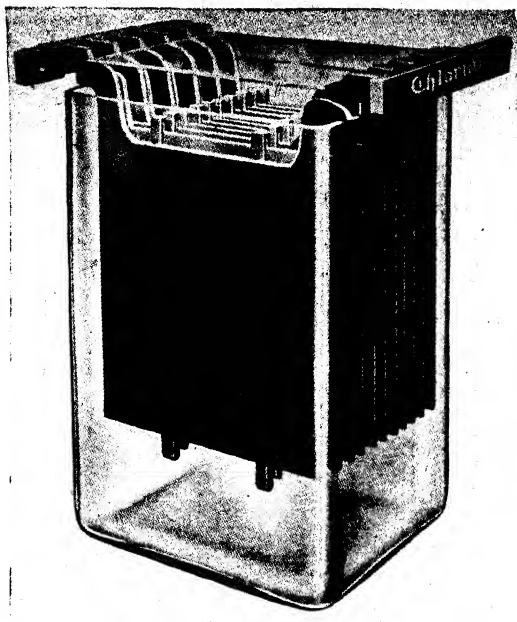
No. 702.—Chloride Planté Cell.

(Five positive plates and six negative plates.)

Ampere hours = 306 at 10-hour discharge rate.
Final voltage = 1·83 volts.

An emergency battery on these lines can be used for the purpose of guaranteeing the supply to the steering motors at all times, and further, for maintaining lighting in essential compartments below deck such as the engine-room.

Note.—By " trickle charge " is meant continuous charging of the battery at a very low rate of charge, and usually amounts to about 2 per cent. of the battery capacity in 10 hours, distributed over a period of 24 hours.

A smaller type of emergency supply equipment is shown in diagram No. 700, the particular application for this being boat deck panic lighting, or engine-room emergency lighting. In this case the battery is of low voltage only, say 25, 50, or 100 volts. The automatic control, as before, provides for continuous trickle rate charging to keep the battery charged and in good condition, this system much reducing the amount of supervision necessary under older methods. As will be seen, trickle charging takes place through a high resistance such as lamps from the main ship supply, usually 220 volts, and a heavier resistance switched into circuit when required to give the higher rate of charge to replace the capacity after emergency use of the battery.

The automatic contactor disconnects the charging circuit, and connects the battery to a circuit of emergency lamps as soon as the normal lighting circuit is interrupted.

The appearance of the small control panel for engine-room emergency lighting is shown in the photograph on p. 1008.
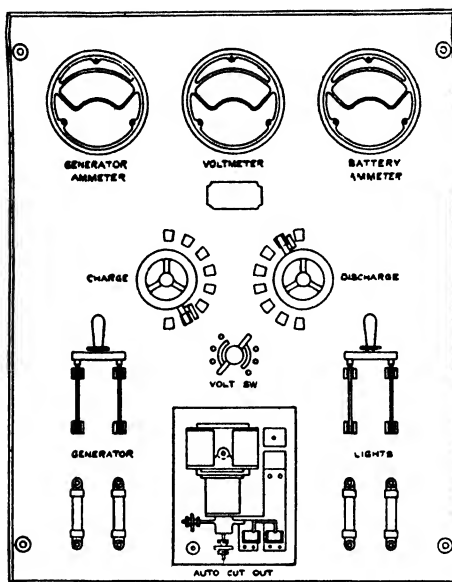
No. 703.—Switchboard for Accumulator Charging
System.
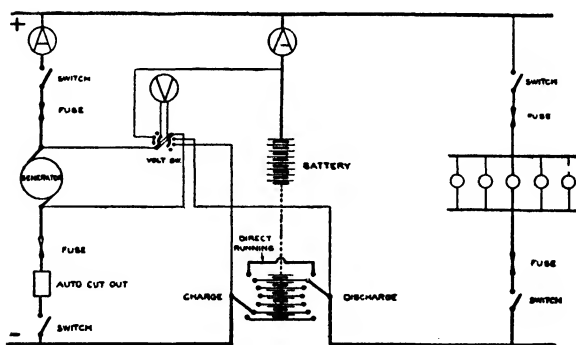
No. 704.—Diagram for Connections of
Switchboard.

The voltmeter is arranged to register (1) the charging volts, (2)
the battery volts, and (3) the discharging current volts. A charging
and a discharging regulating switch for the cutting out or insertion
of cells as may be required completes the fittings.   A circuit
breaker is also sometimes provided as shown.

SAFETY HAND TORCH FOR OIL TANK INSPECTION

(Downs Engineering Works Ltd., London)

Approved by the Ministry of Mines for use in explosive atmospheres.
The torch is gastight and watertight, and is used on board oil tankers.
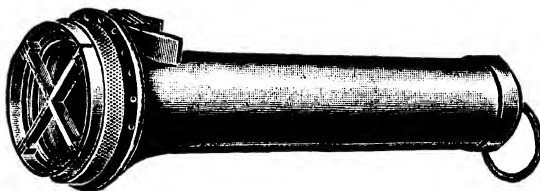
External View.

Advantages.

High lighting efficiency.   Minimum number of parts.
Minimum weight.   Effective sealing of all gastight joints.
Durability.   Standard battery and bulb for easy replacement.

The body, bezel ring, and switch slide are die cast in modified silicon aluminium to Admiralty specification.

The reflector is chromium plated, untarnishable, parabolic type, and fitted with a focusing bulb holder.

The plate glass disc is protected by a duralumin guard. (This guard does not affect the lighting efficiency.)
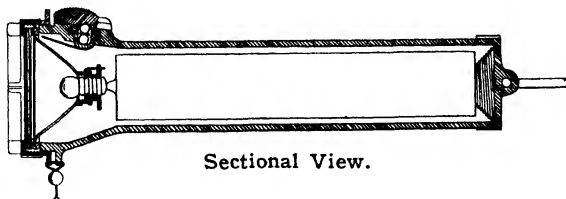
Sectional View.

All detachable parts are secured by one seal.

The switch spring is held in a recess by a hat-shaped rubber diaphragm secured by a screwed plunger guide, the spring is operated by a switch slide acting on two balls through the rubber diaphragm.

The bulb is a standard 3.5 volt spotlight type. It is held in the bulb holder, which is adjustable in the reflector to allow for variations in the filament, and is removed from the back of the reflector to prevent damaging the plating.

SECTION XIII

METRIC SYSTEM, CALCULATIONS, AND LOGARITHMS

I.H.P. and Efficiency (Metric System)

IN the metric system the unit of work is measured by the kilogram metre (kg. m.), viz., the amount of work necessary to lift 1 kg. through 1 m. Therefore 1 H.P. is equal to 75 kg. m. per sec. (75 kg. m./s.), which is the work necessary to lift 75 kg. 1 m. in 1 sec.

The English and metric system H.P. is practically the same (1 English H.P. = 75 kg. m.).

The formula for horse power can be written :—

$$H.P. = \frac{kg. \times m.}{75 \times sec.}$$

The developed H.P. in the engine is calculated by means of the indicator cards (I.H.P.).

The formula for I.H.P. in a 4-cycle Diesel engine (English system) is :—

$$I.H.P. = \frac{P \times A \times L}{75} \times \frac{N}{2 \times 60} \times n.$$

P stands for mean indicated pressure in the cylinder. Calculated by the indicator
    cards, in kilograms per square centimetre (kg./cm².).
A is the area of the cylinder bore in square centimetres.
L is the length of the stroke in metres.
N is revolutions per minute, which is divided by 2 (as only every second stroke is
    a power stroke) and by 60 to get the revolutions per second.
n is the number of working cylinders.
The figures for A L do not alter with the load. They are always the same.
    NOTE.—If a 2-cycle engine, omit the figure 2 shown.

Therefore for each size of Diesel engine a cylinder constant (*C*) can be calculated as follows :—

$$C = \frac{\frac{D^2 \times 11}{14} \times L}{75 \times 2 \times 60} = \frac{A \times L}{9000}.$$

This simplifies the I.H.P. formula to

$$I.H.P. = P \times C \times N \times n.$$

* $\dfrac{33000 \times 12 \text{ in.}}{39\cdot37 \text{ in.} \times 2\cdot204 \times 60} = 76$, but 75 is usually taken as a convenient figure for rapid calculation.

NOTE.—One metre = 39·37 in.; one kilogram = 2·204 lbs.

The engine load is termed brake horse power (B.H.P.), and is calculated by means of a water brake or a dynamo when the Diesel engine is tested in the workshop. The B.H.P. is equal to the I.H.P. minus the H.P. lost by friction in the engines, bearings, working surfaces, compressor, etc.

The mechanical efficiency is found by dividing B.H.P. by I.H.P.

$$\text{Mech. Efficiency} = \frac{B.H.P.}{I.H.P.}$$

Example.—A 4-cylinder Diesel engine, revs. 225, M.I. pressure 7·28 kg./cm²., gives 200 B.H.P. at full load, cylinder diam. 325 mm., length of stroke 440 mm. ; therefore—

$$C = \frac{32·5^2 \times 11 \times 4·4}{9000} = ·0404 \text{ Constant.}$$

NOTE.—$\frac{325}{10} = 32·5$ centimetres, and $\frac{440}{100} = 4·4$ metres.

Now, $\qquad$ I.H.P. $= P \times C \times N \times n$
$\qquad\qquad\qquad = 7·28 \times ·0404 \times 225 \times 4 = 265$ (nearly).

Then, $\qquad$ Mech. Eff. $= \frac{B.H.P.}{I.H.P.} = \frac{200}{265} = ·756.$

Or, $\quad$ 75·6 per cent. of I.H.P.

The H.P. lost in friction is $265 - 200 = 65$ H.P., which is approximately constant at all loads. The most economical load is therefore obtained at full power. The efficiency of a steam engine can reach 90 per cent. of the I.H.P. In a Diesel engine, the air compressors take at full load about 10 per cent. of the I.H.P., and the efficiency is correspondingly lower.

Water Brakes.—If a Diesel engine is direct coupled to a water brake, the B.H.P. is found by the formula—

$$B.H.P. = \frac{W \times N}{C}.$$

W is the weight lifted per kilogram.
N the number of revolutions per minute.
C a constant which depends on the brake.

Dynamos.—If a Diesel engine is coupled to a dynamo, the electric H.P. is calculated from the volts and amperes the dynamo gives off to the outer circuit. An E.H.P. metric system is calculated by—

I. **E.H.P.** = **746** volts × amperes, or 746 watts (W.) (1000 W. is 1 kilowatt (kw.)).

In a dynamo a certain amount of power is used in the inner circuit to overcome resistance, etc., and this loss is not indicated by the volt and ampere gauges on the switchboard.

The B.H.P. of the Diesel engine includes the power used by both

the outer and inner circuit. Therefore the efficiency of the dynamo is found by dividing the E.H.P. by the B.H.P.

$$\text{Dynamo efficiency} = \frac{\frac{V \times A}{746}}{B.H.P.} = \frac{\text{Watts}}{746 \times B.H.P.}.$$

(The dynamo efficiency can be had from the maker.)

From above formula is seen that

$$B.H.P. = \frac{\text{Watts}}{746 \times D.\,Eff.}.$$

From full to half load the dynamo efficiency is usually about 90 per cent. For rough calculation at normal load, the following formula is very useful :—

$$B.H.P. = \frac{V \times A}{746 \times \cdot 9} = \frac{W}{671},$$

from which it may be seen that 220 volts and 3 amps. give approximately 1 B.H.P.,

$$\text{as,} \quad \frac{220 \times 3}{671} = 1 \text{ (nearly).}$$

II. Oil Consumption.

The economical result of a Diesel plant depends directly on the fuel oil consumed per B.H.P. or K.W.; but as these figures again depend on the I.H.P., it is important to have a small oil consumption per I.H.P. The engineer in charge should regularly ascertain this figure by taking several sets of indicator cards; at the same time read the total fuel oil consumed during at least two hours. After having calculated the I.H.P. from the cards, the fuel consumption per I.H.P. is found by

$$\frac{\text{Oil per hour}}{I.H.P.} = \text{oil consumpt. per I.H.P. hour.}$$

When the efficiency of the Diesel engine is known from the maker, the oil consumed per B.H.P. is equal to

$$\frac{\text{Oil per hour}}{B.H.P.} = \text{oil consumpt. per B.H.P. hour.}$$

Load on Thrust Block.

The total pressure on the block can be calculated as follows :—

$$\text{Total thrust} = \frac{I.H.P. \times 33000 \times \cdot 70}{\text{Speed of ship per min.}} = \text{lbs.}$$

NOTE.—The effective horse power delivered to the thrust block is approximately equal to 70 per cent., or ·70 of the total I.H.P.

Example—

I.H.P. = 3000.

Speed = 10½ knots.

Then, $\text{Thrust} = \dfrac{3000 \times 33000 \times \cdot 70}{\dfrac{10 \cdot 5 \times 6080}{60}} = \dfrac{3000 \times 33000 \times \cdot 70 \times 60}{10 \cdot 5 \times 6080} = 65131 \text{ lbs.}$

EFFICIENCY

Table of Trial. Below are Trial Results of a Diesel Engine with a Normal Load of 200 k.w.

Load in Percentage.	No. of Cylinders.	Blast Pressure in Atmos.	Revs. per Min.	Volts.	Amps.	Kilowatts.	Dynamo Efficiency.	B.H.P.	Mean Pressure, kg. cm².	I.H.P.	Oil Consumption in Kilograms.				Mechanical Efficiency.
											Total Oil per Hour.	Oil per K.W. Hour.	Oil per B.I.P. Hour.	Oil per I.H.P. Hour.	
Per Cent.							Per Cent.								Per Cent.
102	4	60	205	220	925	204	90·8	307	6·57	410	60·5	·296	·197	·147	75
77	4	60	209	225	690	155	91	232	5·38	344	48	·310	·207	·135	67·5
50	4	52	212	220	454·5	100	90	150	4·05	259	35	·350	·233	·135	62·6

The oil consumption which this table shows at the different loads should easily be obtained by an average Diesel engine, as it was taken at a preliminary trial of a new engine.

Many makers have, for instance, obtained a fuel oil consumption per B.H.P. of ·185 kg. (roughly, ·41 lb.) at full load. As ·135 kg. per I.H.P. (which is reached at three-quarters and half load) is about the lowest obtainable, it will be seen from the table that the motor needs a better adjustment at full load or that the blast pressure very likely has been too low, as the same pressure was also kept at three-quarter load, viz., 60 atmospheres.

British and Metric Equivalents for Length, Area, Volume, Pressure, and I.H.P.

LENGTH—

$$1 \text{ Metre} = 39 \cdot 37 \text{ inches.}$$

Then, $\dfrac{\text{Inches}}{39 \cdot 37} = \text{Metres, or, Metres} \times 39 \cdot 37 = \text{Inches.}$

$$1 \text{ Centimetre} = 39 \cdot 37'' \div 100 = \cdot 3937 \text{ inch.}$$
$$1 \text{ Millimetre} = 39 \cdot 37'' \div 1000 = \cdot 03937 \text{ inch.}$$

Therefore $\dfrac{1}{\cdot 393} = 2 \cdot 54$ Centimetres per inch.

And $\dfrac{1}{\cdot 0393} = 25 \cdot 4$ Millimetres per inch, or, say, 25.

Again, $\dfrac{\text{Millimetres}}{10} = \text{Centimetres.}$

And $\dfrac{\text{Centimetres}}{100} = \text{Metres.}$

Also, $\dfrac{\text{Millimetres}}{1000} = \text{Metres.}$

AREA—

1 square Centimetre $= \cdot 393^{2} = \cdot 155$ of one square inch.

So that $\dfrac{1^{2}}{\cdot 155} = 6 \cdot 45$ square Centimetres per square inch,

1 square foot $= 144$ square inches.

And $144 \times 6 \cdot 45 = 929$ square Centimetres per square foot.

VOLUME—

1 cubic Centimetre $= \cdot 393^{3} = \cdot 0609$ of a cubic inch.

Then, $\dfrac{1^{3}}{\cdot 0609} = 16 \cdot 4$ cubic Centimetres per cubic inch.

WEIGHT—

$$1 \text{ ounce} = 28 \cdot 35 \text{ Grams.}$$
$$1 \text{ pound} = 453 \cdot 5 \text{ Grams, or } \cdot 4535 \text{ Kilogram.}$$

As $\qquad 16 \times 28 \cdot 35 = 453 \cdot 5.$

And $\qquad 453 \cdot 5 \div 1000 = \cdot 4535$ Kilogram.

$$1 \text{ cwt.} = 50 \cdot 8 \text{ Kilograms.}$$

As $\qquad 112 \times \cdot 4535 = 50 \cdot 8 \qquad ,,$

$$1 \text{ ton} = 1016 \qquad ,,$$

As $\qquad 2240 \times \cdot 4535 = 1016.$

PRESSURE—

Pounds per square inch $= \text{Kilograms per square Centimetre} \times 14 \cdot 22.$

,, ,, ,, $\times \cdot 0703 = \text{Kilograms per square Centimetre.}$

1 foot-pound $= \cdot 1382$ Metre Kilograms.

Then,

33000 foot-pounds $\times \cdot 1382 = 4500$ Metre Kilograms per minute (H.P.)

To Find I.H.P. (Steam)—

Rule—

$$\frac{A \times S \times 2 \times M.E.P. \times Revs.}{4500} = I.H.P.$$

Where A = Piston area in square Centimetres.

,,   S = Stroke in Metres.

,,   M.E.P. = Mean pressure in kilograms per square Centimetre.

,, 1 I.H.P. = 4500 Metre Kilograms per minute.

Note.—The H.P. calculated by the Metric system is slightly in excess of that obtained by the British standard (as 1 : 1·013).

To Find I.H.P. (4-Stroke Diesel Oil Engine)—

$$\frac{A \times S \times M.E.P. \times Revs.}{4500 \times 2} = I.H.P.$$

Note.—Number of firing strokes = Half Number of Revs.

To Find I.H.P. (2-Stroke Diesel Oil Engine)—

$$\frac{A \times S \times M.E.P. \times Revs.}{4500} = I.H.P.$$

Note.—Number of firing strokes = Number of Revs.

TO CONVERT—

Piston area in square inches × 6·45 = Area in square Centimetres.

Stroke in inches ÷ 39·37″ = Stroke in Metres.

Pressure per square inch × ·0703 = Pressure Kilograms per square Centimetre (Kilogram metres).

Example 1.

Work out by both British and Metric systems the total horse power of a 4-stroke Diesel engine set, which consists of six cylinders, each 22″ diameter; stroke, 30″; M.E.P., 90 lbs. per ☐; and revolutions, 140. Assume equal M.E.P. in each cylinder.

(1) British H.P. $= \dfrac{22^2 \times \frac{11}{14} \times 2 \cdot 5 \times 90 \times 140}{33000 \times 2} = 181 \cdot 3.$

And   181·3 × 6 = 1087·8 total H.P.

(2) Metric H.P. $= \dfrac{22^2 \times \frac{11}{14} \times 6 \cdot 45 \times \frac{30}{39 \cdot 37} \times 90 \times \cdot 0703 \times 140}{4500 \times 2} = 187 \cdot 5.$

And   187·5 × 6 = 1125 total H.P.

Example 2.

Work out the H.P. of a Diesel 4-stroke engine, which is fitted with six cylinders, each 508 millimetres diameter; stroke, 762 millimetres; M.E.P., 6·5 kilograms per square centimetre; and revolutions, 130. Assume equal M.E.P. in each cylinder.

Then, H.P. $= \dfrac{\left(\frac{508}{10}\right)^2 \times \frac{11}{14} \times \frac{762}{1000} \times 6 \cdot 5 \times 130}{4500 \times 2} = 145.$

And   145 × 6 = 870 total H.P. of engine.

Note.—Millimetres ÷ 10 = Centimetres, hence $\frac{508}{10}$ = 50·8 Centimetres

$\dfrac{\text{Millimetres}}{1000}$ = Metres, hence $\frac{762}{1000}$ = ·762 Metre.

COMPRESSION OF GASES.

Boyle's Law and Charles's Law Combined

For **perfect gases** the equation connecting pressure, volume, and temperature is as follows :—

1. $$\frac{P_1 \times V_1}{T_1} = \frac{P_2 \times V_2}{T_2}.$$

2. $$\frac{P_1 \times V_1}{T_1} = \text{Constant, or } \frac{P_2 \times V_2}{T_2} = \text{Constant.}$$

3. $$P_1 \times V_1 \times T_2 = P_2 \times V_2 \times T_1.$$

4. Then, $$T_1 = \frac{P_1 \times V_1 \times T_2}{P_2 \times V_2}.$$

5. Or, $$T_2 = \frac{P_2 \times V_2 \times T_1}{P_1 \times V_1}.$$

6. Or, $$P_2 = \frac{P_1 \times V_1 \times T_2}{V_2 \times T_1}$$

7. Or, $$P_1 = \frac{P_2 \times V_2 \times T_1}{V_1 \times T_2}.$$

Where P = Absolute pressure per square inch.
,, V = Volume.
,, T = Absolute temperature, or Fahr. $+ 460°$.

Temperature of Compression.

By calculation the temperature due to adiabatic compression can be found as follows :—

$$T_2 = T_1 \times \left(\frac{V_1}{V_2}\right)^{1·4 - 1}.$$

Where T_1 = Initial absolute temperature.
,, T_2 = Final   ,,   ,,
,, V_1 = Initial volume.
,, V_2 = Final   ,,

Example.—Find the temperature after compression if the initial temperature is 60° F. and the volumes 108 and 9 respectively.

Then, $T_1 = 60° + 460° = 520°$ absolute.
And   log 520 = 2·7160.
,,   108 ÷ 9 = 12 (compression ratio).
,,   log 12 = 1·0792.
Then,   log T_2 = 2·7160 + (1·0792 × ·4) = 3·1476.
So that   de-logarising, 3·1476 = 1405° F.
Or,   1405° − 460° = 945° F. **Ans.**

Compression Ratio.

By this is meant the number of times the volume of suction air is compressed in the cylinder during the upstroke of the piston. In practice this averages about 13·5 times. As, however, $P \times V^{1·4} = C$, it follows that the increase of pressure is much more than that obtained by multiplying 14·7 by ·13·5 (198 lbs.) and which obtains in Boyle's Law.

Example 1.—Find the compression ratio if the clearance volume is equal to 8 per cent. of the stroke volume.

Then,	$V_1 = (8 + 100) = 108$ per cent.
And,	$V_2 = 8$ per cent.
So that,	Compression ratio $= \dfrac{108}{8} = 13\cdot5$.

Example 2.—The clearance volume is equivalent to $2\frac{1}{2}$ in. lineal clearance, and the stroke is 30 in. Find the compression ratio.

Then
$$\frac{30 + 2\cdot5}{2\cdot5} = 13. \quad \text{Ans.}$$

Example 3.—Find the pressure of the compressed air, if the compression ratio is 12.

Then,	$P_2 = P_1 \times \left(\dfrac{V_1}{V_2}\right)^{1\cdot4}$	Where	P_1 = Absolute pressure before compression.
„	$P_2 = 14\cdot7 \times (12)^{1\cdot4}$	„	P_2 = Absolute pressure after compression.
Now,	log of $14\cdot7 = 1\cdot1673$.	„	V_1 = Initial volume.
„	„ $12 = 1\cdot0792$.	„	V_2 = Final volume.
Then,	log $P_2 = 1\cdot1673 + (1\cdot0792 \times 1\cdot4) = 2\cdot6781$.		
And,	de-logarising $2\cdot6781 = 476\cdot5$ lbs. 🔲 Ans.		

In Diesel engine calculations the exponent for compression and expansion is usually taken as between $1\cdot33$ and $1\cdot4$ which assumes adiabatic conditions. In actual running, however, both compression and expansion are only approximately adiabatic in nature, as heat is, of necessity, given up through the cylinder walls to the jacket cooling water.

The higher the revolution speed the nearer will be the approach to adiabatic conditions of compression and expansion.

Example 4.—If the initial pressure of a gas is 200 lbs. gauge, the temperature 400° F. and volume 2 cub. ft., find the volume when the gas expands down to a pressure of 20 lbs. and temperature of 260° F.

Then,	$200 + 14\cdot7 = 214\cdot7 = P_1$.
	$20 + 14\cdot7 = 34\cdot7 = P_2$.
	$400 + 460 = 860 = T_1$.
	$260 + 460 = 720 = T_2$.
	$2 = V_1$.
Now,	$\dfrac{214\cdot7 \times 2}{860} = \dfrac{34\cdot7 \times V_2}{720}$.
So that	$214\cdot7 \times 2 \times 720 = 34\cdot7 \times 860 \times V_2$.
Therefore,	$V_2 = \dfrac{214\cdot7 \times 2 \times 720}{34\cdot7 \times 860} = 10\cdot3$ cub. ft. Ans.

Example 5.—

$$P_2 = 34\cdot7, \ V_2 = 10\cdot35, \ T_2 = 720.$$
Find T_1 if $P_1 = 214\cdot7$ and $V_1 = 2$.

Then,	$214\cdot7 \times 2 \times 720 = 34\cdot7 \times 10\cdot35 \times T_1$.
So that	$T_1 = \dfrac{214\cdot7 \times 2 \times 720}{34\cdot7 \times 10\cdot35} = 860°$ absolute.
And	$860 - 460 = 400°$ F. Ans.

Theoretical Heat Efficiency.

The maximum efficiency of any heat engine working on the Carnot cycle is expressed by the formula—

$$\text{Efficiency} = \frac{T_1 - T_2}{T}.$$

Where T_1 = Absolute initial temperature.
,,　　T_2 =　　,,　　final　　,,

Example 1.—Find the ideal efficiency of an engine which works between temperatures of 150° F. and 400° F.

Then,　　　　　　150° + 460° = 610 absolute.
And　　　　　　　400° + 460° = 860　　,,

$$\text{Efficiency} = \frac{860 - 610}{860} = \cdot 29, \text{ or } 29 \text{ per cent. Ans.}$$

Example 2.—Find the theoretical efficiency, of a heat engine which works between temperatures of 80° F. and 1200° F.

Then,　　　　　　80° + 460° = 540° absolute.
And　　　　　　　1200 + 460° = 1660°　　,,

$$\text{Efficiency} = \frac{1660 - 540}{1660} = \cdot 674, \text{ or } 67 \cdot 4 \text{ per cent. Ans.}$$

In practice only about 50 per cent. of this efficiency is obtained under the best conditions.

Then,　　　Practical efficiency = ·674 × ·5 = ·337, or 33·7 per cent.

Importance of Compression.

In Diesel practice correct and full compression is all important, as the firing temperature and efficiency is entirely dependent on this function of the stroke.

In practice, the compression ratio by volume ranges from 12 to 14, but the pressure ratio is much higher, owing to the fact that temperature comes into the question.

In the case of high piston speeds the compression is chiefly adiabatic in nature.

Example.—Assume initial temperature of suction atmospheric air in cylinder to be 200° at beginning of compression, find the gauge pressure of compression at end of stroke, assuming the temperature to be, say, 1000° F., and the compression ratio 14 (neglecting adiabatic conditions).

Then, by Boyle's Law (constant temperature),

As,　　1 : 14 :: 14·7 : 205·8 lbs. at constant temperature.

Also, by Charles's Law (constant heat),

As,　　(200 + 460°) : (1000 + 460°) :: 205·8 : 455 lbs. abso.

Gauge pressure = 455 − 15 = 440 lbs. compression.

The above simple calculations show how Boyle's Law and Charles's Law can be combined.

NOTE.—The results obtained are only approximate, as the expansion index ($PV^{1\cdot 35}$) has been, for the sake of simplicity, neglected. Poor compression results in bad firing, or missfiring, and the combustion being incomplete the efficiency and power of the engine both fall off.

Compression Temperatures (Approximate).

Pressure at commencement of compression stroke =   14·7 lbs. abso.

,,	$\frac{1}{2}$	,,	,,	= (say) 44	,, ,,
,,	$\frac{3}{4}$	,,	,,	= ,, 85	,, ,,
,,	end	,,	,,	= ,, 500	,, ,,

Volume at commencement of compression stroke = 100 + 8 = 108 p. cent.

,,	$\frac{1}{2}$	,,	,,	= 50 + 8 = 58	,,
,,	$\frac{3}{4}$	,,	,,	= 25 + 8 = 33	,,
,,	end	,,	,,	= 0 + 8 = 8	,,

The clearance volume is taken as 8 per cent. of stroke volume and the pressures given represent average practice, as measured on a good diagram card, assuming initial temperature of air to be, say, 140° F.

Boyle's Law and Charles's Law combine $\Big\}$ $\dfrac{P_1 \times V_1}{T_1} = \dfrac{P_2 \times V_2}{T_2}$

NOTE.—Pressures and temperatures are both to be expressed in absolute units, that is :—

Gauge pressure + 14·7 = P

Temp. Fahr. + 460° = T

(1) At $\frac{1}{2}$-stroke (in)

$$\frac{14\cdot7 \times 108}{600°} = \frac{44 \times 58}{T_2}$$

So that, $T_2 = \dfrac{44 \times 58 \times 600°}{14\cdot7 \times 108} = 964°$ abso.

and, 964° − 460° = 504° F. Ans.

(2) At $\frac{3}{4}$-stroke (in)

$$\frac{14\cdot7 \times 108}{600°} = \frac{85 \times 33}{T_2}$$

So that, $T_2 = \dfrac{85 \times 33 \times 600}{14\cdot7 \times 108} = 1060°$ abso.

and, 1060° − 460° = 600° F. Ans.

(3) At end of stroke (in)

$$\frac{14\cdot7 \times 108}{600°} = \frac{500 \times 8}{T_2}$$

So that, $T_2 = \dfrac{500 \times 8 \times 600°}{14\cdot7 \times 108} = 1511°$ abso.

and, 1511° − 460° = 1051° F. Ans.

NOTE.—To obtain accurate results the exponent 1·33, or 1·35, should be employed, which, however, entails the use of Logarithms in the calculation.

$$P_1 \times V_1^{1\cdot35} = P_2 \times V_2^{1\cdot35}$$

$$\tfrac{3}{4} \qquad \tfrac{1}{2} \qquad \tfrac{1}{4}$$

8

$$\leftarrow - 33 - \rightarrow$$
$$\leftarrow - - 58 - - \rightarrow$$
$$\leftarrow - - - 83 - - - \rightarrow$$
$$\leftarrow - - - - 108 - - - - \rightarrow$$

$$108 = V_1$$
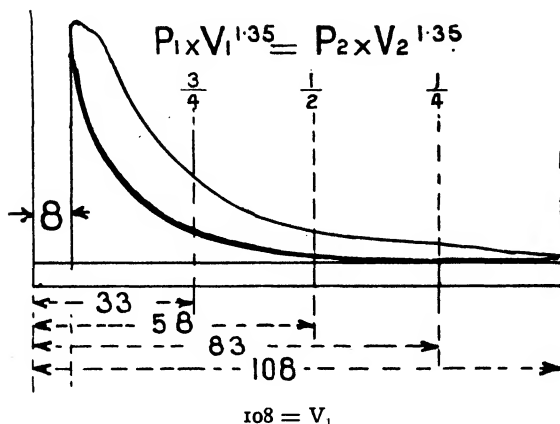
No. 705.

Law of Compression.

As air compression is partly adiabatic and partly isothermal in nature, the index or exponent usually accepted as approximately correct for calculation purposes ranges between $1\cdot33$ and $1\cdot35$ in design work.

Taking the index as $1\cdot35$:—

$$\text{Then,} \quad P_1 \times V_1^{1\cdot35} = P_2 \times V_2{}^{1\cdot35}$$

The temperature of the compressed air at different positions of the stroke can then be calculated as follows :—

(1) **From pressures,** $\quad T_2 = T_1 \times \left(\dfrac{P_2}{P_1}\right)^{\left(\frac{1\cdot35-1}{1\cdot35}\right)}$

(2) **From volumes,** $\quad T_2 = T_1 \times \left(\dfrac{V_1}{V_2}\right)^{(1\cdot35-1)}$.

NOTE : $\dfrac{1\cdot35 - 1}{1\cdot35} = \cdot259$ Also, $1\cdot35 - 1 = \cdot35$

Where T_1 = Absolute temperature of air at commencement of compression stroke (often taken as $60° + 460° = 520°$).

,, T_2 = Absolute temperature at end of compression.

,, V_1 = Volume of air at commencement of compression stroke (say 100 per cent. plus per cent. clearance volume).

,, V_2 = Clearance volume (say 8 per cent.).

,, P_1 = Initial air absolute pressure (say $14\cdot7$ lbs.).

,, P_2 = Final air absolute pressure.

,, $1\cdot35$ = Exponent for combined isothermal and adiabatic compression.

The expansion pressures and temperatures can also be calculated by the methods shown for compression, which, it may be pointed out, require the use of common logarithms.

Then, at position (1) ¼-stroke, $V_2 = 108 - 25 = 83$
  ,,   ,,   (2) ½   ,, $V_2 = 108 - 50 = 58$
  ,,   ,,   (3) ¾   ,, $V_2 = 108 - 75 = 33$
  ,,   ,,   (4) end of stroke, $V_2 = 108 - 100 = 8$

At ¼-stroke, $560° \times \left(\dfrac{108}{83}\right)^{(1.35 - 1)} =$

                       $560° \times (1.3)^{.35} =$
Log $1.3 = .1139$ (from table), and $.1139 \times .35 = .039865$.
Anti-log $.039865 = 1.096$ (from table).
Then, $560° \times 1.096 = 613.76°$ abso.
And, $613° - 460° = 153°$ F.

At ½-stroke, $560° \times \left(\dfrac{108}{58}\right)^{(1.35 - 1)} =$

                       $560° \times (1.86)^{.35} =$
Log $1.86 = .2695$ (from table), and $.2695 \times .35 = .094325$.
Anti-log $.09432 = 1.243$ (from table).
Then, $560° \times 1.243 = 696°$ abso.
And $696° - 460° = 236°$ F.

At ¾-stroke, $560° \times \left(\dfrac{108}{33}\right)^{(1.35 - 1)} =$

                       $560° \times (3.27)^{.35} =$
Log $3.27 = .5145$ (from table), and $.5145 \times .35 = .18$.
Anti-log $.18 = 1.514$ (from table).
Then, $560° \times 1.514 = 847.8°$.
And $847.8° - 460° = 387.8°$ F.

At end of stroke, $560° \times \left(\dfrac{108}{8}\right)^{(1.35 - 1)} =$

                       $560 \times (13.5)^{.35}$
Log $13.5 = 1.303$ (from table), and $1.303 \times .35 = .456$.
Anti-log $.456 = 2.858$ (from table).
Then, $560° \times 2.858 = 1600$ abso.
And $1600° - 460° = 1140°$ F.

If pressures are given instead of volumes (say from a diagram card) the temperatures can then be calculated as follows :—

$$T_2 = T_1 \times \left(\frac{P_2}{P_1}\right)^{\left(\frac{1.35 - 1}{1.35}\right)}$$

Where T_2 = Absolute temperature of air at any part of compression stroke.
   ,, P_2 = Pressure at any part of compression stroke.
   ,, P_1 = Pressure at commencement of compression (14.7 lbs. atmospheric).

Observe that $\dfrac{1.35 - 1}{1.35} = .259$. So that the equation becomes $T_2 = T_1 \times \left(\dfrac{P_2}{P_1}\right)^{.259}$

Example.—Find the compressed air temperature when the piston is at $\frac{3}{4}$-stroke (in) and the pressure at that position measures, say, 60 lbs. gauge on the diagram card, the initial air temperature being, say, 100° F.

Then,
$$T_2 = (100° + 460°) \times \left(\frac{60+14\cdot7}{14\cdot7}\right)^{\cdot259} =$$
$$560° \times (5)^{\cdot259}$$

Log   5 = ·699 (from table), and ·699 × ·259 = ·181.
Anti-log   ·181 = 1·517 (from table).
Then,   560° × 1·517 = 849° abso.
And   849° — 460° = 389° F.

Compression Curves compared, together with the corresponding Pressures and Temperatures.

1. For Boyle's law of isothermal or constant temperature compression,
$$P_1 \times V_1 = P_2 \times V_2.$$

2. For compression of air in stage compressors,
$$P_1 \times V_1^{1\cdot2} = P_2 \times V_2^{1\cdot2}.$$

3. For compression of air in Diesel engine cylinders,
$$P_1 \times V_1^{1\cdot35} = P_2 \times V_2^{1\cdot35}.$$

4. For adiabatic compression of air,
$$P_1 \times V_1^{1\cdot4} = P_2 \times V_2^{1\cdot4}.$$

Compression of air in stage compressors is only approximately isothermal. Compression of air in Diesel engine cylinders is only approximately adiabatic.

Data—
Stroke volume = 100 (say, cubic feet).
Clearance   „   = 10 („   „   ).
P_1 = 14·7 lbs. absolute.
V_1 = (100 + 10) = 110.
V_2 = 10.
T_1 = 60° F. + 460° = 520° absolute.

1. Isothermal Compression.
Then,
$$14\cdot7 \times 110 = P_2 \times 10.$$
$$P_2 = \frac{14\cdot7 \times 110}{10} = 161 \text{ lbs. absolute.}$$
$$T_2 = 60° \text{ F. (constant temperature).}$$

2. Compression of Air in Stage Compressors.

Then,
$$14 \cdot 7 \times 110^{1 \cdot 2} = P_2 \times 10^{1 \cdot 2}.$$

So that
$$P_2 = 14 \cdot 7 \times \left(\frac{110}{10}\right)^{1 \cdot 2} = 14 \cdot 7 \times 11^{1 \cdot 2},$$

$\log 11 = 1 \cdot 0414$, and $1 \cdot 0414 \times 1 \cdot 2 = 1 \cdot 2496$.
Antilog $1 \cdot 2496 = 17 \cdot 76$.

Then,
$$P_2 = 14 \cdot 7 \times 17 \cdot 76 = 261 \text{ lbs. absolute.}$$

Now,
$$T_2 = T_1 \times \left(\frac{V_1}{V_2}\right)^{1 \cdot 2 - 1} = 520 \times 11^{\cdot 2},$$

$\log 11 = 1 \cdot 0414$, and $1 \cdot 0414 \times \cdot 2 = \cdot 2082$.
Antilog $\cdot 2082 = 1 \cdot 615$.

Then,
$$T_2 = 520 \times 1 \cdot 615 = 840^\circ \text{ nearly.}$$

And
$$840^\circ - 460^\circ = 380^\circ \text{ F.}$$

3. Compression in Diesel Engine Cylinders.

Then,
$$14 \cdot 7 \times 110^{1 \cdot 35} = P_2 \times 10^{1 \cdot 35}.$$

So that
$$P_2 = 14 \cdot 7 \times \left(\frac{110}{10}\right)^{1 \cdot 35} = 14 \cdot 7 \times 11^{1 \cdot 35},$$

$\log 11 = 1 \cdot 0414$, and $1 \cdot 0414 \times 1 \cdot 35 = 1 \cdot 4058$.
Antilog $1 \cdot 4058 = 25 \cdot 46$.

Then,
$$P_2 = 14 \cdot 7 \times 25 \cdot 46 = 374 \text{ lbs. absolute.}$$

Again,
$$T_2 = T_1 \times \left(\frac{V_1}{V_2}\right)^{1 \cdot 35 - 1} = 520 \times 11^{\cdot 35},$$

$\log 11 = 1 \cdot 0414$, and $1 \cdot 0414 \times \cdot 35 = \cdot 3644$.
Antilog $\cdot 3644 = 2 \cdot 314$.

$$T_2 = 520^\circ \times 2 \cdot 314 = 1203^\circ \text{ absolute.}$$

And
$$1203^\circ - 460^\circ = 743^\circ \text{ F.}$$

4. Adiabatic Compression.

Then,
$$14 \cdot 7 \times 110^{1 \cdot 4} = P_2 \times 10^{1 \cdot 4}.$$

So that
$$P_2 = 14 \cdot 7 \times \left(\frac{110}{10}\right)^{1 \cdot 4} = 14 \cdot 7 \times 11^{1 \cdot 4},$$

$\log 11 = 1 \cdot 0414$, and $1 \cdot 0414 \times 1 \cdot 4 = 1 \cdot 4579$.
Antilog $1 \cdot 4579 = 28 \cdot 70$.

$$P_2 = 14 \cdot 7 \times 28 \cdot 7 = 422 \text{ lbs. absolute (nearly).}$$

Now,
$$T_2 = T_1 \times \left(\frac{V_1}{V_2}\right)^{1 \cdot 4 - 1} = 520 \times 11^{\cdot 4},$$

$\log 11 = 1 \cdot 0414$, and $1 \cdot 0414 \times \cdot 4 = \cdot 4165$.
Antilog $\cdot 4165 = 2 \cdot 609$.

$$T_2 = 520^\circ \times 2 \cdot 609 = 1356^\circ \text{ absolute.}$$

And
$$1356^\circ - 460^\circ = 896^\circ \text{ F.}$$

Note.—The table of logarithms (p 1041) requires to be referred to for the various logs and antilogs shown in the working out of the respective pressures and temperatures.

CALCULATIONS BY LOGARITHMS

Complicated calculations, such as those involving the expansion and compression of gases, can be made easy by the use of common logarithms, and the marine engineering student is strongly advised to master the principles involved in the use of " logs," as they are usually called.

Use of Logarithms.—Logarithms can be employed in multiplication, division, involution, and evolution, etc.

Logarithms Defined.—Ordinary logs refer to a base number of 10, and are often spoken of as " to the base 10," as this number multiplied by itself one or more times gives the log value of the expression.

Thus,
$$10^0 = \quad 1 = \text{Log } 0.$$
$$10^1 = \quad 10 = \quad \text{,, } 1$$
$$10^2 = \quad 100 = \quad \text{,, } 2.$$
$$10^3 = \quad 1000 = \quad \text{,, } 3.$$
$$10^4 = 10000 = \quad \text{,, } 4.$$

So that $\quad\quad 10^0 = 1$ (the base) and log 0.

Therefore, $\quad\quad 10^1 = 10$ and log 1.

Logarithms may thus be defined as the index of the power to which the base (10) requires to be raised to produce the number required.

Ordinary numbers represent arithmetical progression, while logs represent the corresponding geometrical progression of these numbers.

Example.

Arithmetical increase = 0, 1, 2, 3, 4, 5.
Geometrical   ,,   = 1, 2, 4, 8, 16, 32.

Numbers and logs compared.

Number	-	-	1000	100	10	1
Logs	-	-	3	2	1	0

Or,
$$1000 = 10^3 = \text{Log } 3.$$
$$100 = 10^2 = \quad \text{,, } 2.$$
(Base) $\quad 10 = 10^1 = \quad \text{,, } 1.$
$$1 = 1 = \quad \text{,, } 0.$$

Observe that the *index* of the power required forms the *log* of the corresponding number.

Logs in Use.—Two systems of logarithms are in general use: (1) the ordinary logs to the base 10, and expressed as $\log_{10}$, and (2) hyperbolic or Naperian logs, expressed as log, these latter being chiefly employed in calculations relating to the expansion of, and work done, by steam.

Characteristic.—By this is meant the figure or figures on the *left* of the decimal portion of the log.

Mantissa.—By this is meant the *decimal* portion of the log as given in the log tables, and which always retains a *positive* value.

Figures in Characteristic.—(Whole numbers *or whole* numbers and decimals.)   The number of figures in the characteristic on any log is *one less* than the number of figures before the decimal point of the number itself.

Thus,	For 200 (3 figures) the characteristic	= 2.
	,, 3200 (4 ,,) ,, ,,	= 3.
	,, 150 (3 ,,) ,, ,,	= 2.
	,, 90 (2 ,,) ,, ,,	= 1.
	,, 25 (2 ,,) ,, ,,	= 1.
	,, 9 (1 ,,) ,, ,,	= 0.

When the number required consists of decimals only, then the reverse holds good, that is, the characteristic is formed of one *more figure* than the number of decimal ciphers appearing in the number, and is of negative value.

Thus,	For ·102 (no ciphers) the characteristic	= — 1 or $\bar{1}$.
	,, ·016 (1 cipher) ,, ,,	= — 2 or $\bar{2}$.
	,, ·008 (2 ciphers) ,, ,,	= — 3 or $\bar{3}$.
	,, ·0008 (3 ciphers) ,, ,,	= — 4 or $\bar{4}$.

Observe that the minus sign is placed *above* the characteristic, as the mantissa is *always positive*.

Therefore for positive values the characteristic contains **one** *less* figure than the number, and for negative values one *more* figure than the number of decimal noughts (if any) contained in the number.

Logarithm Table.

	Numbers.										Fourth Figure Additions.							
	0	1	2	3	4	5	6	7	8	9	1 2 3	4 5 6	7 8 9					
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1 3 4	6 7 9	10 11 13					

Example 1.—Find log of 30.

Observe that the first column gives 4771, which must always be read off as a *decimal number*, or ·4771. Then, as 30 consists of two *whole* numbers, the log of 30 = 1·4771, the index or characteristic having one whole number less.

Example 2.—Find log of 301.

Then, under the second column of the Table, the mantissa is 4786, or ·4786, so that log 301 = 2·4786. Notice that the log index has *one less* whole number than 301, that is 2, or 2·4786 as given.

Example 3.—Find log of 306.

Under column 6 the mantissa is given as 4857, or ·4857, and as we have three whole numbers in 306, the log index will consist of two whole numbers.

Therefore,   **Log 306 = 2·4857.**

Had the log of 30·6 been required, the answer would then have been—

Log 30·6 = 1·4857.

Also,   **Log 3·06 = ·4857.**

Log 3060 = 3·4857.

Observe that in 3060 there are four whole numbers; the log index, therefore, consists of three whole numbers, and so on.

Again the log of 30600 = 4·4857, because 30600 = five whole numbers, and the log index contains one less, or four whole numbers, hence 4·4857.

Example 4.—Find log of 3052.

Under column 5 the mantissa is given as 4843, but as we still have the figure 2 to allow for, therefore refer to the Difference Table on right, and under figure 2 at top we find the figure 3, and this figure has to be added on to the previous mantissa—

Thus,   **4843 + 3 = 4846, or ·4846.**

So that   **The log of 3052 = 3·4846.**

Remember that the odd figures in the Difference Table have always to be added to the mantissa as first found, and *before the decimal point is placed in position* on the left of the mantissa : this is important.

Example 5.—Find log of 3089.

Under column 8 we find 4886, but as we still have the 9 to allow for, refer to Difference Table, and under figure 9 we find 13.   This has to be added to the 4886 previously found—

Then,	4886 + 13 = 4899.
So that	The log of 3089 = 3·4899.
Similarly,	The log of 308·9 = 2·4899.
	„ „ 30·89 = 1·4899.
	„ „ 3·089 = ·4899.

Observe that the mantissa is the same for similar figures independent of the position of the decimal point, but note carefully that the log index is different each time, always being *one less* than the whole numbers in the original figures

Example 6.—Find log of 86·87.

Look up the Table of logs (p. 1042), and at 86 under column 8 we find 9385, which is the mantissa of 868, but as we still have the 7 to allow for, refer to the Difference Table, and under 7 we find the figure 4, which requires to be added on to the 9385 previously found.

Then,		9385 + 4 = 9389.				
So that	Log 86·87	= 1·9389 (log index one less than 2).				
	„ 868·7	= 2·9389 (	„	„	„	3).
	„ 8687	= 3·9389 (	„	„	„	4).
	„ 8·687	= 9389 (	„	„	„	1).

Example 7.—Find log of 101.

Referring to Table, p. 1041, in line with 10 and under 1 we find 0043, which is of course ·0043.

So that	Log of 101 = 2·0043	Log index always one figure
	„ 10·1 = 1·0043	less than figures in number
	„ 1·01 = ·0043	given.

Logs of Decimal Numbers.

If the number given consists of decimals only, then the log index is negative also, and is *one figure higher* than the number of decimal o's in the original number.

Thus,	For ·0018 the log index = $\bar{3}$ (same as − 3).
	„ ·018 „ „ = $\bar{2}$ („ − 2).
	„ ·18 „ „ = $\bar{1}$ („ − 1).

Observe that the minus sign is placed *above* the index because the mantissa is *always positive*.

Example 1.—Find log of ·006.

Look up the Table, and at 60 we find the mantissa to be 7782, as we have two decimal ciphers in the original number, then the characteristic or index will consist of the figure −3, or, as it is expressed, 3̄.

So that   Log of ·006   = 3̄·7782⎫ Log index to be <u>one more</u>
         „   ·0006   = 4̄·7782⎬ than number of decimal o's
         „   ·00006 = 5̄·7782⎭ in number.
         „   ·6   = 1̄·7782⎭

Example 2.—Find log of ·09848.

Refer to Table, and opposite 98 and under column 4 we find 9930, which is the mantissa for 984, but as we still have the 8 to allow for, look up Difference Table, and under 8 we find 4 as the number to be added to the first mantissa, then 9930+4 = 9934 as correct mantissa for 9848.

So that   Log ·09848   = 2̄·9934⎫
         ., ·009848 = 3̄·9934⎬Decimals, log index one more
         „ ·0009848 = 4̄·9934⎭ than number of decimal o's.
         „ ·9848   = 1̄·9934⎭
         „ 9·848   = ·9934⎫ Whole numbers, log index
         ., 98·48   = 1·9934⎬one less than number of
         „ 984·8   = 2·9934⎭ whole numbers.
         „ 9848   = 3·9934⎭

Observe that the mantissa is constant for all similar figures whether decimals or whole numbers.

Exercises.

1. Find the log of 200.
2.   „   „   „ 100.
3.   „   „   „ 20.
4.   „   „   „ ·5·
5.   „   „   „ 350.
6.   „   „   „ ·00035.
7.   „   „   „ 2·875.
8.   „   „   „ 287·5.

9.   Find the log of ·625.
10.   „   „   „ 2·875.
11.   „   „   „ ·0625.
12.   „   „   „ 6·25².
13.   „   „   „ √1728.
14.   „   „   „ ³√512.
15.   „   „   „ 3·1416.
16.   „   „   „ ·7854.

Answers.

1 - - - 2·3010.
2 - - - 2·0000
3 - - - 1·3010.
4 - - - 1̄·6990.
5 - - · 2·5441.
6 - - - 4̄·5441.
7 - - · ·4587.
8 - - - 2·4587.

9 - - · 1̄·7959.
10 - - · ·45867.
11 - - - 2̄·7959.
12 - - - 1·5918.
13 - - - 1·61875.
14 - - · ·9031.
15 - - · ·4970.
16 - - · 1̄·8951.

Addition and Subtraction of Logs.—It should be carefully noted by the student that in the working out of logs, *algebraic* addition and subtraction must be carried out.

Multiplication by Logs—Multiplication by logs is performed by adding together the logs of the numbers, which addition gives the log of the answer.

Division by Logs.—Division by logs is performed by subtracting the logs of the numbers, which subtraction gives the log of the answer.

Involution by Logs.—Involution, or the raising of the power of a number, is performed by multiplying the log of the number by the power index (2 for square root and 3 for cube root), and the result is the *log* of the answer.

Evolution by Logs.—Evolution, or the extraction of roots, is performed by dividing the log of the number by the root index (divide by 2 for square root, and by 3 for cube root), and the result is the *log* of the answer.

Observe that in the above cases of multiplication, division, involution, and evolution, the result obtained is only *the log* of the answer required, so that the table of antilogs must be referred to for the actual number wanted.

Antilogs.—Tables of antilogs are exactly the reverse of log tables, and are required to convert given logs (delogarise) into the corresponding numbers, so that we require both a table of logarithms and a table of antilogarithms.

Given a number the log can be found from the table of logs.

Given a log the number can be found from the table of antilogs.

Conversion of Antilogs.—Suppose the log obtained by certain calculations is 2·9170, then to find the corresponding value of this in figures, neglect the log index altogether and refer to the antilog table, where, opposite ·91 and under column 7, we find 8260 : now, as the log index is 2 (one less than the whole numbers of the figures required), we mark off three figures from left to right, and place the decimal point in position.

So that   Log 2·9170 = 826·0 (or simply 826).

„ 1·9170 = 82·6.

„   ·9170 =   8·26.

Example 1.—Log = 3·8626. Find corresponding number or antilog.

Neglect index 3 of log, and from Antilog Table (p. 1045) opposite ·86, and under column 2, we find 7278, which is the numerical value

of ·862, but as we have still the figure 6 to allow for, refer to Difference Table, where under 6 we find 10, which has to be added on to the 278 previously found—

Then,	$7278 + 10 = 7288.$
So that	$7288 = 3·8626$ log.

Observe that the log index is 3, therefore the answer consists of *four* whole numbers, hence 7288.

Again, 728·8	$= 2·8626$ log	⎫ For whole numbers, index
72·88	$= 1·8626$,,	figure is one less than number
7·288	$= ·8626$,,	⎭ of whole numbers
·7288	$= \bar{1}·8626$,,	
·07288	$= \bar{2}·8626$,,	⎫ For decimals, index figure
007288	$= \bar{3}·8626$,,	is one more than number of
·0007288	$= \bar{4}·8626$,,	⎭ decimal ciphers

Example 2.—Log $= \bar{3}·2678$.   Find corresponding number.

Refer to Antilog Table, p. 1043 (as reproduced below), and opposite ·26 and under column 7 we find 1849 ; to allow for the last figure 8, refer to Difference Table, where, under column 8, we find figure 3 to be added on to 1849, hence $1849 + 3 = 1852.$

	Antilogarithms.												Fourth Figure Additions.						
	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
·26	1820	1824	1828	1832	1837	1841	1845	1849	1854	1858	0	1	1	2	2	3	3	3	4

Then as the log index $= \bar{3}$ the number will have *two* decimal ciphers before the figures as found above.

So that	·001852	$= \text{Log } \bar{3}·2678$	⎫ With decimals, the log index
Again,	·01852	$= ,, \bar{2}·2678$	(minus) is one figure higher than
			the number of decimal ciphers
			⎭ in the number.
	·1852	$= ,, \bar{1}·2678$	
	1·852	$= ,, ·2678$	⎫ With whole numbers, the log
	18·52	$= ,, 1·2678$	index (positive) is one less than
	185·2	$= ,, 2·2678$	the number of whole numbers.
	1852	$= ,, 3·2678$	⎭

Warning.—The student must be warned against the somewhat natural error of reading antilogs for logs during calculations, as, having perhaps first looked up an antilog for one part of the working, he may, in looking up the log for the next part, inadvertently refer again to the antilog table, forgetting to turn back to the table of logs ; this mistake is very often made by the beginner in logarithms

Addition and Subtraction of Index and Mantissa

It must be carefully noted that the mantissa of a log taken from the tables is *always positive*, whereas the index or characteristic may be either positive or negative. Therefore, in addition or subtraction of logs (as required in multiplication or division of numbers) the mantissa portion of the log must either be added or subtracted as simple arithmetical terms, but when dealing with the index the sign laws of algebra must be followed out.

In carrying over a figure from the mantissa to the index, which may occur in either addition or subtraction, the figure carried over is always *positive*.

Addition.

Example 1.—Add together log 3·4286 and log 2·8126.

Then,
$$+ 3·4286$$
$$+ 2·8126$$
$$\overline{6·2412} \text{ Ans.}$$

8 added to 4 = 12, and the 1 carried is + 1.

So that   + 3 + 2 + 1 = + 6 or 6.

Example 2.—Add together log 2·2125 and log − 5·3832.

Then,
$$+ 2·2125$$
$$- 5·3832$$
$$\overline{- 3·5957} \text{ Ans.}$$

Observe that − 5 + 2 = − 3.

Example 3.—Add together log 2·8976 and log 3·9090.

Then,
$$+ 2·8976$$
$$+ 3·9090$$
$$\overline{+ 6·8066} \text{ Ans.}$$

The plus signs are not really required, but are shown for the sake of clearness.

Example 4.—Add together log $\bar{3}$·9832 and log 2·9963.

Then,
$$\bar{3}·9832$$
$$+ 2·9963$$
$$\overline{ ·9795} \text{ Ans.}$$

Observe that + 1 carried over from the mantissa addition gives + 3, therefore + 3 − 3 = 0.

Example 5.—Add together log $1\cdot3075$ and log $\bar{4}\cdot6191$.

Then,
$$+\ 1\cdot3075$$
$$\bar{4}\cdot6191$$
$$-\ 3\cdot9266 \text{ Ans.}$$

Example 6.—Add together log $\bar{3}\cdot9009$ and log $\bar{2}\cdot9978$.

Then,
$$\bar{3}\cdot9009$$
$$\bar{2}\cdot9978$$
$$\bar{4}\cdot8987 \text{ Ans.}$$

Observe that the $+\ 1$ carried over from the mantissa addition gives $-5 + 1 = -4$.

Subtraction.

Example 1.—From $3\cdot9557$ subtract $2\cdot9528$.

Then,
$$+\ 3\cdot9557 = +\ 3\cdot9557$$
$$+\ 2\cdot9528 \quad -\ 2\cdot9528 \text{ (sign changed)}$$
$$+\ 1\cdot0029 \text{ Ans.}$$

Observe that in algebraic subtraction the sign is changed of the number to be subtracted, then algebraic addition follows :—

Example 2.—From $5\cdot2532$ subtract $\bar{2}\cdot7882$.

Then,
$$+\ 5\cdot2532$$
$$\bar{2}\cdot7882$$
$$6\cdot4650 \text{ Ans.}$$

Observe that the $+\ 1$ carried over from the mantissa arithmetical subtraction gives for the lower figure $-2 + 1 = -1$, and changing the sign of $-$ to $+$ we obtain $+5 + 1 = +6$ (or 6) as the index of the log.

Example 3 —From $\bar{3}\cdot8938$ subtract $\bar{4}\cdot9782$

Then,
$$\bar{3}\cdot8938$$
$$\bar{4}\cdot9782$$
$$\cdot9156 \text{ Ans.}$$

Observe that 9 from 18 leaves 9, and carry $+\ 1$ to -4, which then gives -3; now change the -3 into $+3$, so that finally -3 above and $+3$ below cancel out, leaving the mantissa only.

Example 4.—From ·4843 take ·5717.

Then,

$$+ ·4843$$
$$+ ·5717$$
$$\overline{1}·9126 \text{ Ans.}$$

Observe that 5 from 14 leaves 9, and carry $+$ 1, which gives 1·9126 ; but as the sign has to be changed, we then obtain $\overline{1}$·9126 as the log answer.

Example 5.—From 6·8350 take 2·9191.

Then,

$$- 6·8350$$
$$2·9191$$
$$\overline{9}·9159 \text{ Ans.}$$

Observe that 9 from 18 leaves 9, and the $+$ 1 carried to the 2 gives $+$ 3 ; as the sign has to be changed we obtain $-$3 and $-6-3 = -9$ as the index.

Exercises.

Addition of Logs.

1. Add together 3·4867 and 1·8762.
2.   „   3·8672, 2·3075, $\overline{5}$·6780, and ·6725.
3.   „ $\overline{3}$·7655, 1·9727, and $\overline{1}$·8232.
4.   „ $\overline{1}$·5238, $\overline{3}$·8265, 2·1760, and $\overline{5}$·0125.

Answers.

1. 5·3629.	3. $\overline{1}$·5616.
2. 2·5252.	4. $\overline{6}$·5388.

Subtraction of Logs.

1. Subtract 3·8265 from 4·3925.   3. Subtract 7·5328 from $\overline{1}$·0099.
2.   „   2·0062 „ $\overline{3}$·0625.   4.   „ $\overline{3}$·2906 „ $\overline{2}$·1668.

Answers.

1. ·5660.	3. $\overline{9}$·4771.
2. 5·0563.	4. ·8762.

Multiplication of Logs.—In raising the power of a number we multiply the log of the number by the power index, and in doing so it is necessary to remember that the multiplication being algebraic, the rule must be adhered to, which is, that like signs (whether plus or minus) multiplied together give positive products, and unlike signs when multiplied give minus products.

Division of Logs.—Division of logs, as required in extraction of roots of numbers, being also algebraic in nature, is similar to multiplication, so that unlike signs when divided give negative or

minus answers, and like signs (whether plus or minus) when divided give plus or positive results.

Example 1.—3·6021 × 3.

Then,

$$
\begin{array}{r}
3\cdot6021 \\
3 \\
\hline
10\cdot8063 \ \text{Ans.}
\end{array}
$$

Example 2.—1·7243 × 2

Then,

$$
\begin{array}{r}
1\cdot7243 \\
2 \\
\hline
3\cdot4486 \ \text{Ans.}
\end{array}
$$

Example 3.—$\bar{2}$·2315 × 2.

Then,

$$
\begin{array}{r}
\bar{2}\cdot2315 \\
2 \\
\hline
\bar{4}\cdot4630 \ \text{Ans.}
\end{array}
$$

Example 4 —$\bar{3}$·9956 × 3.

Then,

$$
\begin{array}{r}
\bar{3}\cdot9956 \\
3 \\
\hline
\bar{7}\cdot9868 \ \text{Ans.}
\end{array}
$$

Observe that the 2 carried over from the mantissa multiplication, being positive, is subtracted from the − 3 × 3 of the index.

Thus, $-9 + 2 = -7 \text{ or } \bar{7}.$

Logs to Antilogs.—Convert the following logs into antilogs :—

1. 2·5867.	5. $\bar{3}$·0632.	9. ·1000.
2. $\bar{1}$·5867.	6. ·9909.	10. ·0625.
3. $\bar{2}$·5867.	7. $\bar{4}$·4267.	11. 2·1009.
4. 3·6258.	8. 2·3000.	12. $\bar{4}$·4837.

Answers

1. 386·1.	5. ·001157.	9. 1·259.
2. ·3861.	6. 9·792	10. ·1154.
3. ·03861.	7. ·0002671.	11. ·01262.
4. 4225.	8. 199·5.	12. ·0003046.

Application of Logarithms. — The various examples which follow show the application of logs to calculations of various kinds, and the advantage of this system will be obvious, particularly, perhaps, in those treating of root extractions (Evolution).

Example 1 —Multiply 687·5 by 8·625.

Then,   Log 687·5 = 2·8373
                         „   8·625 = 0·9358
                         ─────────
                         Sum of logs = 3·7731
So that,   Antilog 3·7731 = 5930 **Ans.**

Observe that the antilog of 7731 = 5930, and as the index is **3**, the whole number is 4, hence 5930 = Answer.

NOTE.—In looking up antilog *ignore index* of the log.

Example 2.—·00655 × 25·62.

Then,   Log   ·00655 = $\bar{3}$·8162
                         „   25·62   = 1·4085
                         ─────────
                         Sum of logs = $\bar{1}$·2247.
So that   Antilog $\bar{1}$·2247 = ·1678 **Ans.**

Observe that + 1 carried to 1 gives + 2, so that − 3 − + 2 = − 1 or $\bar{1}$.

Example 3.—286·25 ÷ 99·82.

Then,   Log 286·25 = 2·4567
                         „   99·82 = 1·9992
                         ─────────
So that,   Difference of log = ·4575
                         Antilog ·4575 = 2·867   **Ans.**

Notice that 10 from 14 leaves 4, and + 1 carried to + 1 = + 2 ; but as in subtraction the sign has to be changed, then + 2 becomes − 2, and this balances the + 2 above, hence the result ·4575.

Example 4.—17·28³.

Then,   Log 17·28 = 1·2375.
And   1·2375 × 3 = 3·7125.
So that   Antilog 3·7125 = 5158 **Ans.**

Example 5.—$\sqrt{144}$.

Then,   Log 144 = 2·1584.
And   2·1584 ÷ 2 = 1·0792.
So that   Antilog 1·0792 12 **Ans.**

Example 6.—$\sqrt[3]{1728}$.

Then,   Log 1728 = 3·2375.
And   3·2375 ÷ 3 = 1·0792 (nearly).
So that   Antilog 1·0792 = 12 **Ans.**

Example 7.—Find value of $(28·25)^{\frac{2}{3}}$.

Then,   Log 28·25 = 1·4510.

Then, $\dfrac{1·4510 \times 2}{3}$ = ·9673.

So that   Antilog ·9673 = 9·274 **Ans.**

Example 8.—Find the value of—

$$14 \times \sqrt{\left(\frac{17 \cdot 5 \times 68}{100}\right)^3}.$$

Then,　　　Log 2200　= 3·3424 ⎫

　　　　　　　,,　　17·5 = 1·2430 ⎪ General reduction of all

　　　　　　　,,　　68　= 1·8325 ⎬　　terms to logs.

　　　　　　　,,　　100　= 2·0000 ⎪

　　　　　　　,,　　14　= 1·1461 ⎭

Therefore,　　　　　　　　1·2430

　　　　　　　　　　　　　1·8325

　　　　　　　　　　　　　‾‾‾‾‾‾

　　　　Sum of logs = 3·0750

　　　　　　　　　　　2·0000

　　　　　　　　　　　‾‾‾‾‾‾

　　Difference of logs = 1·0750, and 1·075 × 3 = 3·225.

Again,　　　　　　　　　　3·3424

　　　　　　　　　　　　　3·225

　　　　　　　　　　　　　‾‾‾‾‾

　　Difference of logs =　·1174, and ·1174 ÷ 2 = ·0587.

Again,　　　　　　　　　　1·1461

　　　　　　　　　　　　　·0587

　　　　　　　　　　　　　‾‾‾‾‾

　　　　Sum of logs = 1·2048

So that　　　Antilog 1·2048 = 16·03　Ans.

Example 9.—The pressure is 160 lbs. gauge, and the specific volume of the gas 2·56 cub. ft. per lb.　Find the value of the constant C if the expansion follows out the law.

$$PV^{\frac{17}{16}} \left(\text{or } PV^{1 \cdot 0652} \right) = \text{Constant.}$$

Rule.

　　　Log C = Log P + 1·0625 log V.

　　　Log V = $\dfrac{\text{Log C} - \text{Log P}}{1 \cdot 0625}$.

　　　Log P = Log C − 1·0625 log V.

Note.　160 + 15 = 175 lbs. absolute.

Then,　　　　　　　Log 175 = 2·2430.

　　　　　　　　　Log 2·56 = ·4082 (nearly).

So that,　　　Log C = 2·2430 + (1·0625 × ·4082) = 2·6767.

And,　　　　　　2·6767 = 475　Constant.

Example 10.—Referring to Example 9, if, during expansion, P falls to 85 lbs. gauge pressure, find the value of V, the volume.

Then,　　　　　　　Log V = $\dfrac{\text{Log C} - \text{Log P}}{1 \cdot 0625}$.

　　　85 + 15 = 100.　Log 100 = 2.　Log C = 2·6767.

So that　　　　　Log V = $\dfrac{2 \cdot 6767 - 2}{1 \cdot 0625}$ = ·6368.

And　　　　　·3668 = 4·33 cubic feet volume.　Ans.

Example 11.—Referring to Example 9, assume that, during expansion, the volume increased from 2·56 cub. ft. to 31·9 cub. ft Find the corresponding pressure.

Then,   Log P = Log C — (1·0625 log V).

                        Log 31·9 = 1·5038.

So that   Log P = 2·6767   (1·0625 × 1·5038) = 1·079.

Therefore,   Antilog = 11·99 (say 12 lbs.) absolute. Ans.

Example 12.—At the beginning of the compression stroke the air pressure in the cylinder is 14 lbs. absolute, the temperature being 100° F. : if, at the end of compression, the pressure is 500 lbs. absolute, find the air temperature, the power index being 1·33.

Where P_1 = 14 lbs.

„ P_2 = 500 lbs.

„ T_1 = 100° + 460° = 560° absolute.

„ T_2 = absolute final temperature.

Then, $$T_2 = T_1 \times \left(\frac{P_2}{P_1}\right)^{\frac{1\cdot33-1}{1\cdot33}}$$

Then, $$T_2 = 560 \times \left(\frac{500}{14}\right)^{\cdot248}$$

Method of Working.

$$\frac{1\cdot33-1}{1\cdot33} = \cdot248.$$

$$500 \div 14 = 35\cdot71.$$

Log 35·71 = 1·5528 from Table.

Now,   1·5528 × ·248 = ·3850.

Antilog of ·3850 = 2·427 from Table.

Then,   2·427 × 560° = 1359° absolute.

Fahr. = 1359° — 460° = 899°. Ans.

Example 13.—V_1 = 13·5, V_2 = 1, T_1 = 120° F., find T_2, the power index being 1·4

Then, $$T_2 = T_1 \times \left(\frac{V_1}{V_2}\right)^{1\cdot4-1}$$

$$T_1 = 120° + 460° = 580°.$$

$$580 \times \left(\frac{13\cdot5}{1}\right)^{\cdot4}$$

Method of Working.

$$1\cdot4 - 1 = \cdot4.$$

$$13\cdot5 \div 1 = 13\cdot5.$$

Log 13·5 = 1·1303 from Table.

Now,   1·1303 × ·4 = ·45212.

Antilog of ·45212 = 2·832 from Table.

Then,   2·832 × 580° = 1642° absolute.

Fahr. = 1642° — 460° = 1182°. Ans.

Example 14.—$V_1 = 13 \cdot 5$, $V_2 = 1$, $P_1 = 14$ lbs. absolute, find P_2, if power index $= 1 \cdot 4$.

Then,
$$P_2 = P_1 \times \left(\frac{V_1}{V_2}\right)^{1 \cdot 4}$$

Then,
$$P_2 = 14 \times \left(\frac{13 \cdot 5}{1}\right)^{\cdot 4}$$

Method of Working.

$$13 \cdot 5 \div 1 = 13 \cdot 5.$$
$$\text{Log } 13 \cdot 5 = 1 \cdot 1303 \text{ from Table.}$$

Now,
$$1 \cdot 1303 \times 1 \cdot 4 = 1 \cdot 5824.$$
$$\text{Antilog of } 1 \cdot 5824 = 38 \cdot 23 \text{ from Table.}$$

Then,
$$38 \cdot 23 \times 14 = 535 \text{ lbs. absolute. Ans.}$$

Example 15.—$P_1 = 14$, $P_2 = 535$, $V_1 = 13 \cdot 5$, $V_2 = 1$, find the volume index (n) corresponding to the compression.

Then,
$$P_2 = P_1 \times \left(\frac{V_1}{V_2}\right)^{n}$$

Then,
$$535 = 14 \times \left(\frac{13 \cdot 5}{1}\right)^{n}$$

Method of Working.

$$535 \div 14 = 38 \cdot 21.$$
$$\text{Log } 38 \cdot 21 = 1 \cdot 5821.$$
$$\text{Log } 13 \cdot 5 = 1 \cdot 1303.$$

And,
$$n = \frac{1 \cdot 5821}{1 \cdot 1303} = 1 \cdot 4 \text{ (nearly). Ans.}$$

Example 16.—Find the temperature of the air at the end of the compression stroke, the initial air pressure being 14 lbs. absolute and temperature 80° F. if the final compression pressure is 480 lbs. by gauge, and the value of index, n 1·35 ?

Then,
$$T_2 = T_1 \times \left(\frac{P_2}{P_1}\right)^{\frac{1 \cdot 35 - 1}{1 \cdot 35}}$$

,,
$$T_2 = 540° \times \left(\frac{480 + 14 \cdot 7}{14}\right)^{\cdot 259}$$

,,
$$T_2 = 540° \times (35 \cdot 33)^{\cdot 259}$$

,,
$$T_2 = 540° \times 2 \cdot 512.$$

,,
$$T_2 = 1356° \text{ absolute.}$$

And
$$1356° - 460° = 896° \text{ F. Ans.}$$

Note. —
$$80° + 460° = 540°.$$
$$\text{Log } 35 \cdot 33 = 1 \cdot 5482.$$
$$1 \cdot 5482 \times \cdot 259 = \cdot 400.$$
$$\text{Antilog } \cdot 400 = 2 \cdot 512.$$
$$540° \times 2 \cdot 512 = 1356.$$

First Figures	Third Figure.										Fourth Figure Additions.								
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374	4	8	12	17	21	25	29	33	37
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755	4	8	11	15	19	23	26	30	34
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106	3	7	10	14	17	21	24	28	31
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430	3	6	10	13	16	19	23	26	29
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732	3	6	9	12	15	18	21	24	27
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014	3	6	8	11	14	17	20	22	25
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279	3	5	8	11	13	16	18	21	24
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529	2	5	7	10	12	15	17	20	22
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765	2	5	7	9	12	14	16	19	21
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989	2	4	7	9	11	13	16	18	20
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	2	4	6	8	11	13	15	17	19
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	2	4	6	8	10	12	14	16	18
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	2	4	6	8	10	12	14	15	17
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	2	4	6	7	9	11	13	15	17
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	2	4	5	7	9	11	12	14	16
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133	2	3	5	7	9	10	12	14	15
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	2	3	5	7	8	10	11	13	15
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	2	3	5	6	8	9	11	13	14
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	2	3	5	6	8	9	11	12	14
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	1	3	4	6	7	9	10	12	13
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1	3	4	6	7	9	10	11	13
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1	3	4	6	7	8	10	11	12
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	1	3	4	5	7	8	9	11	12
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	1	3	4	5	6	8	9	10	12
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1	3	4	5	6	8	9	10	11
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	1	2	4	5	6	7	9	10	11
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	1	2	4	5	6	7	8	10	11
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	1	2	3	5	6	7	8	9	10
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	1	2	3	5	6	7	8	9	10
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	1	2	3	4	5	7	8	9	10
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	1	2	3	4	5	6	8	9	10
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222	1	2	3	4	5	6	7	8	9
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	1	2	3	4	5	6	7	8	9
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	1	2	3	4	5	6	7	8	9
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	1	2	3	4	5	6	7	8	9
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618	1	2	3	4	5	6	7	8	9
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	1	2	3	4	5	6	7	7	8
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803	1	2	3	4	5	5	6	7	8
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	1	2	3	4	4	5	6	7	8
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	1	2	3	4	4	5	6	7	8
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067	1	2	3	3	4	5	6	7	8
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	1	2	3	3	4	5	6	7	8
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235	1	2	2	3	4	5	6	7	7
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	1	2	2	3	4	5	6	6	7
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	1	2	2	3	4	5	6	6	7

LOGARITHMS—(*continued*)

First Figures	Third Figure.										Fourth Figure Additions.								
	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	1	2	3	3	4	5	5	6	7
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551	1	2	2	3	4	5	5	6	7
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627	1	2	2	3	4	5	5	6	7
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	1	1	2	3	4	4	5	6	7
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774	1	1	2	3	4	4	5	6	7
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846	1	1	2	3	4	4	5	6	6
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917	1	1	2	3	4	4	5	6	6
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987	1	1	2	3	3	4	5	6	6
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055	1	1	2	3	3	5	5	5	6
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122	1	1	2	3	3	4	5	5	6
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189	1	1	2	3	3	4	5	5	6
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254	1	1	2	3	3	4	5	5	6
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319	1	1	2	3	3	4	5	5	6
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382	1	1	2	3	3	4	4	5	6
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445	1	1	2	2	3	4	4	5	6
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506	1	1	2	2	3	4	4	5	6
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567	1	1	2	2	3	4	4	5	5
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627	1	1	2	2	3	4	4	5	5
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	1	1	2	2	3	4	4	5	5
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745	1	1	2	2	3	4	4	5	5
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802	1	1	2	2	3	3	4	5	5
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	1	1	2	2	3	3	4	5	5
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915	1	1	2	2	3	3	4	4	5
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971	1	1	2	2	3	3	4	4	5
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025	1	1	2	2	3	3	4	4	5
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079	1	1	2	2	3	3	4	4	5
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133	1	1	2	2	3	3	4	4	5
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186	1	1	2	2	3	3	4	4	5
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238	1	1	2	2	3	3	4	4	5
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289	1	1	2	2	3	3	4	4	5
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340	1	1	2	2	3	3	4	4	5
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390	1	1	2	2	3	3	4	4	5
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440	0	1	1	2	2	3	3	4	4
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489	0	1	1	2	2	3	3	4	4
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538	0	1	1	2	2	3	3	4	4
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586	0	1	1	2	2	3	3	4	4
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633	0	1	1	2	2	3	3	4	4
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680	0	1	1	2	2	3	3	4	4
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727	0	1	1	2	2	3	3	4	4
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773	0	1	1	2	2	3	3	4	4
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818	0	1	1	2	2	3	3	4	4
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863	0	1	1	2	2	3	3	4	4
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908	0	1	1	2	2	3	3	4	4
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952	0	1	1	2	2	3	3	4	4
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996	0	1	1	2	2	3	3	3	4

ANTILOGARITHMS·

First Figures of Mantissa	Third Figure.										Fourth Figure Additions.								
	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
·00	1000	1002	1005	1007	1009	1012	1014	1016	1019	1021	0	0	1	1	1	1	2	2	2
·01	1023	1026	1028	1030	1033	1035	1038	1040	1042	1045	0	0	1	1	1	1	2	2	2
·02	1047	1050	1052	1054	1057	1059	1062	1064	1067	1069	0	0	1	1	1	1	2	2	2
·03	1072	1074	1076	1079	1081	1084	1086	1089	1091	1094	0	0	1	1	1	1	2	2	2
·04	1096	1099	1102	1104	1107	1109	1112	1114	1117	1119	0	1	1	1	1	2	2	2	2
·05	1122	1125	1127	1130	1132	1135	1138	1140	1143	1146	0	1	1	1	1	2	2	2	2
·06	1148	1151	1153	1156	1159	1161	1164	1167	1169	1172	0	1	1	1	1	2	2	2	2
·07	1175	1178	1180	1183	1186	1189	1191	1194	1197	1199	0	1	1	1	1	2	2	2	2
·08	1202	1205	1208	1211	1213	1216	1219	1222	1225	1227	0	1	1	1	1	2	2	2	3
·09	1230	1233	1236	1239	1242	1245	1247	1250	1253	1256	0	1	1	1	1	2	2	2	3
·10	1259	1262	1265	1268	1271	1274	1276	1279	1282	1285	0	1	1	1	1	2	2	2	3
·11	1288	1291	1294	1297	1300	1303	1306	1309	1312	1315	0	1	1	1	2	2	2	2	3
·12	1318	1321	1324	1327	1330	1334	1337	1340	1343	1346	0	1	1	1	2	2	2	3	3
·13	1349	1352	1355	1358	1361	1365	1368	1371	1374	1377	0	1	1	1	2	2	2	3	3
·14	1380	1384	1387	1390	1393	1396	1400	1403	1406	1409	0	1	1	1	2	2	2	3	3
·15	1413	1416	1419	1422	1426	1429	1432	1435	1439	1442	0	1	1	1	2	2	2	3	3
·16	1445	1449	1452	1455	1459	1462	1466	1469	1472	1476	0	1	1	1	2	2	2	3	3
·17	1479	1483	1486	1489	1493	1496	1500	1503	1507	1510	0	1	1	1	2	2	2	3	3
·18	1514	1517	1521	1524	1528	1531	1535	1538	1542	1545	0	1	1	1	2	2	2	3	3
·19	1549	1552	1556	1560	1563	1567	1570	1574	1578	1581	0	1	1	1	2	2	3	3	3
·20	1585	1589	1592	1596	1600	1603	1607	1611	1614	1618	0	1	1	1	2	2	3	3	3
·21	1622	1626	1629	1633	1637	1641	1644	1648	1652	1656	0	1	1	2	2	2	3	3	3
·22	1660	1663	1667	1671	1675	1679	1683	1687	1690	1694	0	1	1	2	2	2	3	3	3
·23	1698	1702	1706	1710	1714	1718	1722	1726	1730	1734	0	1	1	2	2	2	3	3	4
·24	1738	1742	1746	1750	1754	1758	1762	1766	1770	1774	0	1	1	2	2	2	3	3	4
·25	1778	1782	1786	1791	1795	1799	1803	1807	1811	1816	0	1	1	2	2	2	3	3	4
·26	1820	1824	1828	1832	1837	1841	1845	1849	1854	1858	0	1	1	2	2	3	3	3	4
·27	1862	1866	1871	1875	1879	1884	1888	1892	1897	1901	0	1	1	2	2	3	3	3	4
·28	1905	1910	1914	1919	1923	1928	1932	1936	1941	1945	0	1	1	2	2	3	3	4	4
·29	1950	1954	1959	1963	1968	1972	1977	1982	1986	1991	0	1	1	2	2	3	3	4	4
·30	1995	2000	2004	2009	2014	2018	2023	2028	2032	2037	0	1	1	2	2	3	3	4	4
·31	2042	2046	2051	2056	2061	2065	2070	2075	2080	2084	0	1	1	2	2	3	3	4	4
·32	2089	2094	2099	2104	2109	2113	2118	2123	2128	2133	0	1	1	2	2	3	3	4	4
·33	2138	2143	2148	2153	2158	2163	2168	2173	2178	2183	0	1	1	2	2	3	3	4	4
·34	2188	2193	2198	2203	2208	2213	2218	2223	2228	2234	1	1	2	2	3	3	4	4	5
·35	2239	2244	2249	2254	2259	2265	2270	2275	2280	2286	1	1	2	2	3	3	4	4	5
·36	2291	2296	2301	2307	2312	2317	2323	2328	2333	2339	1	1	2	2	3	3	4	4	5
·37	2344	2350	2355	2360	2366	2371	2377	2382	2388	2393	1	1	2	2	3	3	4	4	5
·38	2399	2404	2410	2415	2421	2427	2432	2438	2443	2449	1	1	2	2	3	3	4	4	5
·39	2455	2460	2466	2472	2477	2483	2489	2495	2500	2506	1	1	2	2	3	3	4	5	5

ANTILOGARITHMS—(*continued*)

First Figures of Mantissa	Third Figure.										Fourth Figure Additions.								
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
·40	2512	2518	2523	2529	2535	2541	2547	2553	2559	2564	1	1	2	2	3	4	4	5	5
·41	2570	2576	2582	2588	2594	2600	2606	2612	2618	2624	1	1	2	2	3	4	4	5	5
·42	2630	2636	2642	2649	2655	2661	2667	2673	2679	2685	1	1	2	2	3	4	4	5	6
·43	2692	2698	2704	2710	2716	2723	2729	2735	2742	2748	1	1	2	3	3	4	4	5	6
·44	2754	2761	2767	2773	2780	2786	2793	2799	2805	2812	1	1	2	3	3	4	4	5	6
·45	2818	2825	2831	2838	2844	2851	2858	2864	2871	2877	1	1	2	3	3	4	5	5	6
·46	2884	2891	2897	2904	2911	2917	2924	2931	2938	2944	1	1	2	3	3	4	5	5	6
·47	2951	2958	2965	2972	2979	2985	2992	2999	3006	3013	1	1	2	3	3	4	5	5	6
·48	3020	3027	3034	3041	3048	3055	3062	3069	3076	3083	1	1	2	3	4	4	5	6	6
·49	3090	3097	3105	3112	3119	3126	3133	3141	3148	3155	1	1	2	3	4	4	5	6	6
·50	3162	3170	3177	3184	3192	3199	3206	3214	3221	3228	1	1	2	3	4	4	5	6	7
·51	3236	3243	3251	3258	3266	3273	3281	3289	3296	3304	1	2	2	3	4	5	5	6	7
·52	3311	3319	3327	3334	3342	3350	3357	3365	3373	3381	1	2	2	3	4	5	5	6	7
·53	3388	3396	3404	3412	3420	3428	3436	3443	3451	3459	1	2	2	3	4	5	6	6	7
·54	3467	3475	3483	3491	3499	3508	3516	3524	3532	3540	1	2	2	3	4	5	6	6	7
·55	3548	3556	3565	3573	3581	3589	3597	3606	3614	3622	1	2	2	3	4	5	6	7	7
·56	3631	3639	3648	3656	3664	3673	3681	3690	3698	3707	1	2	3	3	4	5	6	7	8
·57	3715	3724	3733	3741	3750	3758	3767	3776	3784	3793	1	2	3	3	4	5	6	7	8
·58	3802	3811	3819	3828	3837	3846	3855	3864	3873	3882	1	2	3	4	4	5	6	7	8
·59	3890	3899	3908	3917	3926	3936	3945	3954	3963	3972	1	2	3	4	5	5	6	7	8
·60	3981	3990	3999	4009	4018	4027	4036	4046	4055	4064	1	2	3	4	5	6	6	7	8
·61	4074	4083	4093	4102	4111	4121	4130	4140	4150	4159	1	2	3	4	5	6	7	8	9
·62	4169	4178	4188	4198	4207	4217	4227	4236	4246	4256	1	2	3	4	5	6	7	8	9
·63	4266	4276	4285	4295	4305	4315	4325	4335	4345	4355	1	2	3	4	5	6	7	8	9
·64	4365	4375	4385	4395	4406	4416	4426	4436	4446	4457	1	2	3	4	5	6	7	8	9
·65	4467	4477	4487	4498	4508	4519	4529	4539	4550	4560	1	2	3	4	5	6	7	8	9
·66	4571	4581	4592	4603	4613	4624	4634	4645	4656	4667	1	2	3	4	5	6	7	9	10
·67	4677	4688	4699	4710	4721	4732	4742	4753	4764	4775	1	2	3	4	5	7	8	9	10
·68	4786	4797	4808	4819	4831	4842	4853	4864	4875	4887	1	2	3	4	6	7	8	9	10
·69	4898	4909	4920	4932	4943	4955	4966	4977	4989	5000	1	2	3	5	6	7	8	9	10
·70	5012	5023	5035	5047	5058	5070	5082	5093	5105	5117	1	2	4	5	6	7	8	9	11
·71	5129	5140	5152	5164	5176	5188	5200	5212	5224	5236	1	2	4	5	6	7	8	10	11
·72	5248	5260	5272	5284	5297	5309	5321	5333	5346	5358	1	2	4	5	6	7	9	10	11
·73	5370	5383	5395	5408	5420	5433	5445	5458	5470	5483	1	3	4	5	6	8	9	10	11
·74	5495	5508	5521	5534	5546	5559	5572	5585	5598	5610	1	3	4	5	6	8	9	10	12
·75	5623	5636	5649	5662	5675	5689	5702	5715	5728	5741	1	3	4	5	7	8	9	10	12
·76	5754	5768	5781	5794	5808	5821	5834	5848	5861	5875	1	3	4	5	7	8	9	11	12
·77	5888	5902	5916	5929	5943	5957	5970	5984	5998	6012	1	3	4	5	7	8	10	11	12
·78	6026	6039	6053	6067	6081	6095	6109	6124	6138	6152	1	3	4	6	7	8	10	11	13
·79	6166	6180	6194	6209	6223	6237	6252	6266	6281	6295	1	3	4	6	7	9	10	11	13

ANTILOGARITHMS—*(continued)*

First Figures of Mantissa	Third Figure.										Fourth Figure Additions.								
	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
·80	6310	6324	6339	6353	6368	6383	6397	6412	6427	6442	1	3	4	6	7	9	10	12	13
·81	6457	6471	6486	6501	6516	6531	6546	6561	6577	6592	2	3	5	6	8	9	11	12	14
·82	6607	6622	6637	6653	6668	6683	6699	6714	6730	6745	2	3	5	6	8	9	11	12	14
·83	6761	6776	6792	6808	6823	6839	6855	6871	6887	6902	2	3	5	6	8	9	11	13	14
·84	6918	6934	6950	6966	6982	6998	7015	7031	7047	7063	2	3	5	6	8	10	11	13	15
·85	7079	7096	7112	7129	7145	7161	7178	7194	7211	7228	2	3	5	7	8	10	12	13	15
·86	7244	7261	7278	7295	7311	7328	7345	7362	7379	7396	2	3	5	7	8	10	12	13	15
·87	7413	7430	7447	7464	7482	7499	7516	7534	7551	7568	2	3	5	7	9	10	12	14	16
·88	7586	7603	7621	7638	7656	7674	7691	7709	7727	7745	2	4	5	7	9	11	12	14	16
·89	7762	7780	7798	7816	7834	7852	7870	7889	7907	7925	2	4	5	7	9	11	13	14	16
·90	7943	7962	7980	7998	8017	8035	8054	8072	8091	8110	2	4	6	7	9	11	13	15	17
·91	8128	8147	8166	8185	8204	8222	8241	8260	8279	8299	2	4	6	8	9	11	13	15	17
·92	8318	8337	8356	8375	8395	8414	8433	8453	8472	8492	2	4	6	8	10	12	14	15	17
·93	8511	8531	8551	8570	8590	8610	8630	8650	8670	8690	2	4	6	8	10	12	14	16	18
·94	8710	8730	8750	8770	8790	8810	8831	8851	8872	8892	2	4	6	8	10	12	14	16	18
·95	8913	8933	8954	8974	8995	9016	9036	9057	9078	9099	2	4	6	8	10	12	15	17	19
·96	9120	9141	9162	9183	9204	9226	9247	9268	9290	9311	2	4	6	8	11	13	15	17	19
·97	9333	9354	9376	9397	9419	9441	9462	9484	9506	9528	2	4	7	9	11	13	15	17	20
·98	9550	9572	9594	9616	9638	9661	9683	9705	9727	9750	2	4	7	9	11	13	16	18	20
·99	9772	9795	9817	9840	9863	9886	9908	9931	9954	9977	2	5	7	9	11	14	16	18	20

SECTION XIII
NOTES AND DATA

Rectangular Solid Beams.

Rule. $6 \times \text{B.M.} = \text{D}^2 \times \text{B} \times \text{stress} \boxed{n}$.

Note.—If hollow beams, substitute

$$\left(\frac{\text{D}^3 \times \text{B} - d^3 \times b}{\text{D}} \right) \text{ for D}^2 \times \text{B}.$$

Torsional Stress and T.M. on Circular Sections.

T.M. = Twisting moment, or " torque " = leverage × load.

Rule. $5\cdot 1 \times \text{T.M.} = \text{dia.}^3 \times \text{stress} \boxed{n}$.

Therefore, $\text{Stress} = \dfrac{5 \cdot 1 \times \text{T.M.}}{\text{dia.}^3}$.

If hollow shafting, substitute $\dfrac{\text{D}^4 - d^4}{\text{D}}$ for dia.^{3}

Where D = outer dia.
d = inner dia.

Area of Triangle.

1. Rule. $\dfrac{\text{Base} \times \text{Height}}{2} = \text{Area}$.

2. Rule. $\sqrt{\text{S} \times (\text{S} - a) \times (\text{S} - b) \times (\text{S} - c)} = \text{Area}$.

Where S = half perimeter.
a, b, c = respective sides.

$$\text{Radius of inscribed circle} = \frac{\text{Area of triangle}}{\text{S}}.$$

Centre of area of a triangle $= \dfrac{\text{Height}}{3}$ from each side taken as base.

Volume of cone = Area of base $\times \dfrac{\text{H}}{3}$.

Volume of sphere $= \text{D}^3 \times 1\tfrac{1}{4} \times \tfrac{2}{3} = \text{D}^3 \times \cdot 5236$.

Centrifugal force $= \dfrac{\text{W} \times v^2}{\text{R} \times g}$, or $= \dfrac{\text{W} \times \text{R} \times \text{N}^2}{2935}$.

Where W = Weight.
v = velocity in feet per second.
R = Radius in feet.
g = 32·2 feet per sec. acceleration.
N = Revs. per min.

Shaft Horse-power from Torsion Meter.

$$T.M. \times L' = 140 \times dia.^4 \times a.$$

$$\text{Then,} \quad T.M. = \frac{140 \times dia.^4 \times a}{L'},$$

$$\text{and} \quad S.H.P. \text{ or } B.H.P. = \frac{T.M. \times 2 \times 3 \cdot 14 \times Revs.}{33000}.$$

Where T.M. = torque in foot-lbs.
      L' = length in feet measured.
      a = angle of twist.

Cylindrical Shells (Longitudinal).

Rule. Stress $\boxed{n} \times T'' \times 2 \times$ Joint = Dia.$''$ × Pressure × Factor.

Spheres.

Rule. Stress $\boxed{n} \times T'' \times 4 \times$ Joint = Dia.$''$ × Pressure × Factor.

Riveting and Boiler Shells.

$$\frac{(p - d) \times 100}{p} = \text{Seam section strength.}$$

$$\frac{d^2 \times \cdot 7854 \times N \times 23 \times 100 \times c}{p \times T \times 28} = \text{Rivet section strength.}$$

$c = 1$ for lap joints and $1 \cdot 875$ for D.B.S. joints.

NOTE.—The *joint* strength is equal to the smaller of the two results.

$$\text{Then,} \quad 28 \times 2240 \times T'' \times 2 \times \text{Joint per cent.} =$$
Factor × Dia. in inches × Safe pressure × 100,

Where F = Factor of Safety.

NOTE.—A sphere is equal to double the strength of a cylinder of equal diameter and thickness.

Boyle's Law of Gases.

Rule. $P_1 \times V_1 = P_2 \times V_2 \quad \therefore \quad P_1 \times V_1 \div P_2 = V_2$, etc.

Where P_1 = initial absolute pressure.
      P_2 = terminal absolute pressure.
      V_1 = initial volume.
      V_2 = terminal volume.

NOTE.—V_1 and V_2 include clearance volume.

Total Heat and Latent Heat of Steam.

Rule. Total heat = $1115 + \cdot 3T°$, or $966 - \cdot 7(T° - 212) + T°$.
      Latent heat = $1115 - \cdot 7T°$, or $966 - \cdot 7(T° - 212)$.

B.T.U.'s evaporation = Total heat − $t°$.

Where $t°$ = feed temperature.

Heat Transfer.

Rule.   Lbs. × Specific heat × $(T° - t_1°)$ = lbs. × Specific heat × $(t_1° - t_2°)$

Where $T°$, $t_1°$, and $t_2°$ = temperatures of the two bodies.

Adiabatic Expansion or Compression of Gases.

$$\text{Rule.}\quad P_1 \times V_1^{1.4} = P_2 \times V_2^{1.4}.$$

$$\text{Then,}\quad P_1 \times V_1^{1.4} \div V_2^{1.4} = P_2, \text{ or } P_1 \times V_1^{1.4} \div P_2 = V_2^{1\ 4}.$$

NOTE.—Logs. require to be used in working out.

Falling Bodies, etc.

The rules for falling bodies are as follows :—

Where $g = 32.2$ (acceleration due to gravity).

,, t = Time in seconds.

,, V = Velocity in feet per second.

,, S = Space fallen through in feet.

$$\text{Then}\quad (1)\quad V = g \times t.$$
$$,,\quad (2)\quad t = V \div g.$$
$$,,\quad (3)\quad S = \tfrac{1}{2} \times g \times t^2.$$
$$,,\quad (4)\quad V^2 = 2 \times g \times S.$$

Thrown downwards.

$$\text{Rule.}\quad S = Vt + \tfrac{1}{2}gt^2.$$

Thrown upwards.

$$\text{Rule.}\quad S = Vt - \tfrac{1}{2}gt^2.$$

British and Metric Equivalents.

1 Metre = 39.37 inches.

1 Centimetre = $39.37'' \div 100 = .3937$ inch.

1 Millimetre = $39.37'' \div 1000 = .03937$ inch.

Therefore $\dfrac{1}{.393} = 2.54$ Centimetres per inch.

And $\dfrac{1}{.0393} = 25.4$ Millimetres per inch.

1 square Centimetre = $.393^2 = .155$ of one square inch.

$\dfrac{1^2}{.155} = 6.45$ square Centimetres per square inch.

144 × 6.45 = 929 square Centimetres per square foot.

1 cubic Centimetre = $.393^3 = .0609$ of a cubic inch.

16.38 cubic Centimetres = one cubic inch.

1 cubic Metre = 35.31 cubic feet.

1 ounce = 28.35 Grams.

1 pound = 453.5 Grams, or .4535 Kilogram.

Pounds per square inch = Kilograms per square Centimetre × 14.22.

To convert Kilogram Calories to B.T.U.'s per pound,

then, Kilogram Calories × $\dfrac{9}{5}$ = B.T.U.'s per lb.

One Kilogram Calorie = Heat required to raise 2.2 lbs. fresh water 1° Cent.

10.76 square feet = 1 square Metre.

1 pound fresh water = 7000 Grams.

1 Cubic foot contains 6·25 gallons.
1   ,,   ,,   fresh water weighs 62·5 lbs.
1   ,,   ,,   sea water weighs 64 lbs.

$$\text{Volume of Sphere} = D^3 \times \frac{\pi}{6}.$$

Volume of Cone = Area of Base × $\frac{1}{3}$ Height.
1 Nautical Mile = 6080 feet.
1 Metre = 39·37 inches.
1 Litre = ·22 gallon ; or 2·2 lbs. for fresh water.
1 Kilogramme = 2·2 lbs.
Joule's equivalent = 778 foot-lbs.
Latent Heat (Fahr.) = 966 − ·7(T − 212) T.U. per lb.
Absolute Temp. (Fahr.) = 460 + T.

Simpson's Rule.—To the sum of the first and last ordinates add four times the even ordinates and twice the odd ordinates. Multiply the result· by one-third of the common distance between the ordinates and the product will be the area. Same process may be applied to areas to find volume.

40 to 45 cubic feet bunker capacity is allowed per ton of coal.
38 to 39 cubic feet bunker capacity is allowed per ton of oil fuel.
35 cubic feet of sea water = 1 ton displaced.
35·84 cubic feet of fresh water = 1 ton displaced.
2·305 feet of water or 27·66 inches = 1 lb. per square inch area.
27 cubic inches of sea water = 1 lb. per square inch area.
10 lbs. = 1 gallon of fresh water.
10$\frac{1}{4}$ lbs. = 1 gallon of sea water.

$$\text{To convert Fahr. to Cent.} \quad \frac{(F - 32) \times 5}{9}.$$

$$\text{To convert Cent. to Fahr.} \quad \frac{C \times 9}{5} + 32.$$

Electrical Units.

A *Dyne* is the unit of electrical force, and is equal to 1 gm., with a velocity of 1 cm. per second.

An *Erg* is the electrical unit of work, and is equal to 1 dyne multiplied by 1 cm. space described.

A *Joule* is also a unit of work, and is equal to 1 watt during one second, that is, 1 ampere and 1 volt per second. A joule is equal to 10000000 ergs.

To find the *current strength* in amperes passing through an electrical circuit.

$$\text{Rule.} \quad \frac{\text{Volts}}{\text{Ohms resistance}} = \text{Amperes},$$

$$\text{and} \quad \frac{\text{Volts}}{\text{Amperes}} = \text{Ohms},$$

$$\text{or} \quad \text{Amperes} \times \text{Ohms} = \text{Volts}.$$

By "*potential*" is meant the difference of electrical tension existing between the positive and negative leads.

A *Volt* is the measure of electrical pressure or E.M.F. (Electro-Motive Force).

Or, a Volt is the E.M.F. required to give one Ampere of current against one Ohm resistance.

An *Ampere* is the measure of electrical current, and is taken as the standard flow of electricity in a wire per second, or the current flow required to deposit 1·118 milligrams of silver in one second.

An *Ohm* is the measure of electrical resistance, and is about equal to that of one mile of copper wire $\frac{1}{4}$ in. in diameter, or, more accurately, is equal to the resistance offered by a column of mercury 106·3 cm. in height and 1 sq. mm. in sectional area at a temperature of 32° Fahr.

Volts × *Amperes* = *Watts*.

746 watts are equal to 1 *electrical horse-power*.

Therefore, $\dfrac{\text{Volts} \times \text{Amperes}}{746} = \text{E.H.P.}$, or $\dfrac{\text{Amperes}^2 \times \text{Ohms}}{746} = \text{E.H.P.}$

Watts per second per B.T.U. $= \dfrac{1 \times 778 \times 746 \times 60}{33000} = 1055$ Watts per second.

" Ampere Turns."

By this is meant the result obtained by multiplying the amperes flow in a conductor by the number of turns.

Example.—The amperes flow = 10, and the turns of wire round, say, the magnets = 50.

Then, ampere turns = 10 × 50 = 500 ampere turns.

Electrical Accumulator.

Is a secondary or electrical storage cell. The chemical elements are placed in a jar and immersed in a fluid which acts on them only after a current of electricity from a dynamo has been passed through. After this, they become charged, and are then capable of supplying an independent current on discharging. Each cell is equal to 2 volts E.M.F.

Coulomb.

Is a unit of electrical quantity, and is equal to that which would pass in one second through a resistance of one ohm with an E.M.F. of one volt.

Fuse Wire.

For over 100 amperes use a fuse wire which will blow at about $1\frac{1}{2}$ times the working amperes. The fuse to be of tinned copper material.

Example.—For, say, a 200-ampere circuit the fuse = No. 12 S.W.G. (about ·104") and which will blow at 300 amperes.

Refrigeration.

Latent heat value of Ammonia $= 550$ B.T.U.'s per lb. (at brine tank temp.).
,, ,, CO_2 $= 125$,, ,,
Working pressure of Ammonia $= 170$ lbs. $\boxed{n}$.
,, ,, CO_2 $= 1050$,,
Critical temperature of Ammonia $= 256°$ Fahr.
,, ,, CO_2 $= 88°$,,

CO_2 evaporates at $-120°$ Fahr. under atmospheric pressure.
Ammonia (NH^3) evaporates at $-37°$ Fahr. under atmospheric pressure.
Density of brine, composed of fresh water and calcium chloride, is usually from 1·25 to 1·5 by hydrometer reading (say 45 ounce density).

Oil Fuel.

Expansion of oil $= ·0004$ per degree temperature, for oil with specific gravity between ·8 and ·825.

Example.—Specific gravity of an oil at $60° = ·825$. Find the specific gravity at $110°$.

Then, $(110° - 60°) \times ·0004 = ·02,$
and $·825 - ·02 = ·805.$

Example.—20000 cubic feet of oil is heated from $60°$ to $110°$. Find increase of volume.

Then, $(110° - 60°) \times ·0004 \times 20000 = 400$ cubic feet.
So that total volume $= 20000 + 400 = 20400$ cubic feet.

Burner Output.

The output of a burner varies approximately as the square root of the oil pressure (with same diaphragm).

Suppose pressure to be, say, 50 lbs., and output 300 lbs. per hour, then, with a pressure of, say, 90 lbs. the output would be approximately as follows :—

As $\sqrt{50} : \sqrt{90} :: 300 : 406$ lbs.

Air Supply (by calculation).

$$\text{Pounds air per pound fuel} = 12C + 35\left(H - \frac{O}{8}\right).$$

Where C $=$ per cent. carbon in fuel.
H $=$,, hydrogen in fuel.
O $=$,, oxygen in fuel.

NOTE.—In practice, about 1·4 times the calculated amount would be required.

Heat Value of Fuels.

$$\text{B.T.U.'s per lb.} = 14500\,C + 62100\left(H - \frac{O}{8}\right).$$

Where C $=$ per cent. carbon.
H $=$,, hydrogen.
O $=$,, oxygen.

NOTE.—One pound carbon $= 14500$ B.T.U.'s.
One pound hydrogen $= 62100$ B.T.U.'s.

Composition of Texas Fuel Oil.

Carbon   = 84 per cent.
Hydrogen = 12   ,,
Oxygen   = 2   ,,
Nitrogen $\Big\}$ = 2   ,,
Sulphur

Calorific value = 19476 B.T.U.'s per lb.
Specific gravity at 60° = ·92.
Flash point (close) = 220° Fahr.
Fire point = 250° Fahr.

Specific Gravity and Baumé Hydrometer.

1. Specific Gravity to Baumé $= \left(\dfrac{140}{\text{sp. gr.}}\right) - 130.$

2. Baumé to Specific Gravity $= \dfrac{140}{130 + \text{Baumé}}.$

Close flash point of oils not to be less than 150° Fahr. according to B. of T. and Lloyd's Regulations.

Viscosity is a measure of the fluid friction of the oil, and viscosity is reduced by heating.

Logarithms.

Rule.   To multiply, *add* logs. of numbers.
         To divide, *subtract* logs. of numbers.

Examples.   (1) $640 \times 25\cdot6.$
              (2) $640 \div 25\cdot6.$

(1) Now, log. $640 = 2\cdot8062$ (from table),
    and   log. $25\cdot6 = 1\cdot4082$ (,,   ).
    Then, $2\cdot8062 + 1\cdot4082 = 4\cdot2144,$
and antilog. $4\cdot2144 = 16390.$ Ans. (by logs.).

(2) Now, $2\cdot8062 - 1\cdot4082 = 1\cdot398.$
and antilog. $1\cdot398 = 25.$ Ans. (by logs.).

NOTE.—Log. answers differ slightly from worked-out results owing to the incomplete nature of the log. table figures when four figures are exceeded.

Quadratic Equations.

METHOD.

If an equation contains the terms x^2 and x which are equal to a number, proceed as follows :—

(1) Multiply or divide throughout the equation so that the coefficient of x^2 becomes unity or 1.

(2) Take half the coefficient of x, square it and add to *both* sides of the equation, *no matter* what the sign of x may be.

(3) The side containing x^2, x and the number in (2) is a perfect square, consisting of the form $(x_1 + \text{or} - \tfrac{1}{2} \text{ coefficient of } x)^2$.

(4) Put the sign of x inside the brackets.

Example.
$$8x^2 + 16x = 2496$$
$$x^2 + 2x = 312$$
$$x^2 + 2x + (1)^2 = 312 + (1)^2$$
$$x^2 + 2x + (1)^2 = 313$$
$$(x + 1)^2 = 313. \quad \text{NOTE.} \quad \sqrt{313} = 17.69.$$
$$x + 1 = 17.69$$
$$x = +17.69 - 1 = +16.69. \quad \text{Ans.}$$
$$x = -17.69 - 1 = -18.69. \quad \text{Ans.}$$

NOTE.
$$
\begin{array}{r}
x + 1 \\
x + 1 \\
\hline
x^2 + x \\
+ x + 1^2 \\
\hline
x^2 + 2x + 1^2
\end{array}
$$

The Cosine Rule.

NOTE.—If angle *exceeds* 90°, then take difference of this and $-180°$.

Rule. $\quad C^2 = A^2 + B^2 - 2AB \cos C,$

or, $\quad \cos C = \dfrac{A^2 + B^2 - C^2}{2AB}.$

Example.—1. The angle between two sides of a triangle is 120°, the sides being 16 and 22 respectively. Find length of remaining side.

Solution. $\quad -180 + 120 = -60°$ and $\cos -60° = -.5$ (table).

Then, $\quad C^2 = 16^2 + 22^2 - 2 \times 16 \times 22 \times -.5 =$
$$C^2 = 740 + 352$$
$$C^2 = 1092$$
$$C = \sqrt{1092} = 33.04. \quad \text{Ans.}$$

NOTE.—Two minus signs = plus.

Area of Hexagon.—Area = Side $^2 \times 2.6$.

Surface of Sphere.—Surface = Dia.$^2 \times 3.1416$.

Radian.—One Radian = 57.3°.

Boyle's Law and Charles's Law Combined.
$$\frac{P_1 \times V_1}{T_1} = \frac{P_2 \times V_2}{T_2} \quad \therefore \; P_1 \times V_1 \times T_2 = P_2 \times V_2 \times T_1.$$

Where P_1 = absolute initial pressure (gauge pressure + 14.7).
$\qquad P_2$ = absolute terminal pressure (,, ,, ,,).
$\qquad V_1$ = initial volume.
$\qquad V_2$ = terminal volume.
$\qquad T_1$ = initial absolute temperature.
$\qquad T_2$ = terminal absolute temperature.

NOTE.—Absolute temp. = Temp. Fahr. + 460°.

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